STREET AND ELECTRIC RAILWAYS.

PART II.—TECHNICAL ADVANCES IN THE INDUSTRY.

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GENERAL FIGURES.

The general and detailed figures of the report show a remarkable technical advance in the industry, broadly considered, and when examined closely reveal many interesting changes of condition since the report for 1907. The small increase in the number of operating and lessor companies compares strikingly, for example, with the high percentages of gain in plant equipment, the use of electrical energy, the number of passengers carried, the use of water power, and the employment of electric locomotives in street railway service. Here is evidence of the natural tendency toward the grouping of properties into one unified system, just as the New York Central Railroad grew out of a number of lines, between New York and Chicago, at the terminal of each of which the unfortunate "through" passenger had to transfer, with great inconvenience and loss of time. Another aspect of the data is the growth in size of all the units. The miles of line and of single track increased, respectively, 82.9 per cent and 81.9 per cent in the 10-year period, but the number of cars was only 94,016 in 1912, as compared with 83,641 in 1907 and 66,784 in 1902—an increase of 40.8 per cent for the decade. Relatively, passenger cars increased even less than that—from 60,290 in 1902 to 76,162 in 1912, or 26.3 per cent—but the mere statistics are utterly misleading when one compares the small cars of 1902 with the ponderous and capacious cars of 1912 and of later date, many of them double-deckers, referred to later in this chapter. The increase in passengers carried is also much greater than that in car mileage, a fact due both to the higher density of travel within cities and to the falling off in new construction not only within city limits but also in suburban and rural territory, where the trolley is more or less of a competitor with steam railroads. Both contestants for transportation patronage in the five years seem to have suffered in some way from difficulty in raising new capital, smaller income from larger travel, and lack of the rapid expansion associated with earlier periods. And yet it is obvious to anyone familiar with the conditions that, alike in the city and in the country, the opportunity and necessity for greater transportation facilities have never been more pronounced than in the latter half of the decade ending with 1912 and at the present time. Due to this inadequacy of service, created apparently by discouragement of enterprise, there have resulted a loss of time, a lower land value of suburbs, a lesser tax assessment, and a greater congestion of population paying higher rent for less desirable homes, which if totalized and capitalized would represent a far greater sum than would have been necessary to create these facilities and pay a fair return. Such problems are somewhat aside from the technical ones here discussed, but no one can question their intimate relationship and interaction with the technique of the industry.

POWER-PLANT ENGINEERING.

Conditions described and discussed in the report for 1907 have not changed in any radical degree as to power-plant engineering except in the significant extent to which street-railway systems have ceased in a great many instances to manufacture their own electrical energy and have found it more economical and equally reliable to buy power from the local central station systems. There have, however, been several notable new plants, both steam and hydroelectric, installed during the period for the express purpose of furnishing power for electric transportation. These newer plants mark the passing away of the old "double-deck" plants so familiar in the preceding regime, when the steam engines or steam turbines were set directly over the boilers, a type of design which, from the standpoint of steam economy, is as nearly as possible theoretically correct. Another feature of the newer plants is the introduction of units whose size far outruns anything utilized in the past.

South Boston power plant.—The South Boston Station of the Boston (Mass.) Elevated Railway is a fine example of a plant designed for efficient operation with fluctuating loads.[1] It is part of the general scheme of improvement which has been under way for some years. Ultimately it is to be of 125,000-kilowatt capacity, but at present an output of only 30,000 kilowatts is being produced with two units. The tubular boilers, now sixteen in number, are rated at 600 horsepower on the usual basis of 10 square feet of heating surface per boiler horsepower. The turbine room

[1] Electric Railway Journal, Prof. H. H. Norris, Jan. 4, 1913.

is nearly 500 feet long and about 80 feet wide, and the boiler room is of the same length and only slightly wider. This is a remarkable fact in view of the tendency which has been evident for some time to consider the turbine room, so far as space is concerned, a mere annex to the boiler room. The liberal space allowed in the turbine room in this and other recent plants is partly to accommodate the enormous condensers; partly to provide room for as many auxiliaries on the main floor as possible, and to house the increasingly elaborate and bulky electrical switching and transforming apparatus; and partly to give ample space in which the turbines and generators may be taken apart for inspection and repair. In the Boston plant provision is made for taking care of variable loads by means of forced draft controlled by pressure regulators. These regulators, operated by variation in steam pressure, adjust automatically the speed of stoker engines as well as fan engines to suit the load requirements. The forced draft is necessarily accompanied by liberal combustion chamber space in the boilers, the tubes of which are set high, giving the fuel oportunity to burn before the gases are chilled by the tubes. The stokers, of the seven-retort type, are designed to carry several times the rated boiler load, and the fans are of similar overload capacity, so that the boilers can be forced to generate steam at a rate far greater than their nominal capacity. In fact, the present installation of 9,600 boiler horsepower is counted upon to supply steam for turbo-generators of 45,000-kilowatt (equivalent to about 60,000 horsepower) capacity. As a few boilers will usually be out of commission for cleaning or repairs, the remaining ones must evidently be ready for strenuous duty.

Such forcing for peak loads is now recommended practice for railway plants and in no way injures the boilers. At the same time the necessary investment is kept down. At Boston the result is evident in the small relative size of the boiler room, which is arranged with the firing aisle parallel to the turbine room. This plan has the advantage of convenience in handling and in inspection. The steam header, of 14-inch pipe, is placed in the boiler room 2 feet above the floor near the turbine-room partition and on about the same level as the turbine valves. A high-arch connection is made to each turbine, and excellent flexibility is thus assured. Steam-flow meters are connected in the boiler leads. The utility of such meters in assisting the firemen to keep each boiler steaming properly is recognized, and if the experience of such companies as have been using steam meters establishes the ruggedness of the device, a wide field of usefulness is open before them.

The electric generators are wound for the moderate voltage of 6,600, and this is doubled by means of autotransformers or compensators, which serve also as reactance coils to limit short-circuit currents. The generators are ventilated in a somewhat novel manner, the air being drawn in through large ducts terminating above the boiler room and downward through the generator by the usual internal fans. The air, thus drawn from a considerable elevation, is cool and free from dust.

Indianapolis power plant.—The new plant of the Terre Haute, Indianapolis & Eastern Traction Co. is a good example of up-to-date practice. It has two units installed in 1912–13, out of an ultimate capacity four times as great. The boilers, of which 60 will ultimately be required, are divided into three sections, with the firing aisles perpendicular to the turbine room, somewhat on the order of the familiar unit system. Twelve boilers of 520 horsepower each are installed to provide steam for two 6,000-kilowatt horizontal steam turbines. The ultimate boiler capacity of 31,200 horsepower will supply 48,000 kilowatts of rated turbine capacity. While this boiler allowance appears high, it includes provision for the very large overload rating of the turbines, which are expected to be able to deliver a maximum output of 80,000 kilowatts. The boiler tubes are set 10½ feet above the boiler-room floor, illustrating again the tendency toward liberal combustion space. The boilers are equipped with stokers and differential draft gauges. The absence of the usual coal and ash conveyors is noticeable in the Indianapolis plant, the work being accomplished by an industrial railway system. A narrow-gauge track is located over the coal bunkers and under the ash hoppers, and the cars which run upon this track are hoisted by means of two electric elevators.

Each of the horizontal turbo-alternator units of 6,000-kilowatt capacity discharges its steam into a surface condenser hung from the bottom of the turbine frame. The basement floor is thus kept clear for the accommodation of auxiliaries. The steam piping is of open-hearth steel, and the fittings are of cast steel, which is approved practice in plants using superheated steam. The header is located in the basement about 10 feet below the boiler-room floor, and the steam pipes to the turbines are brought up from below without conspicuous arches in the turbine room.

The Indianapolis station is conspicuous for the neat appearance of the turbine room. The enameled brick walls with simple ornamentation assist the management in instilling into the operatives a sense of pride in keeping the machinery in good order. The glass-inclosed operating gallery is free from the noise of the turbine room, insuring strict attention to switching and to the indications of the instruments. The simplicity of the turbine room is enhanced by the partitioning off of the space occupied by all the switch gear, which is located on several galleries, one over the other, closely adjacent to the turbine room but invisible from it.

Washington, D. C., plant.—An interesting plant which shows at a glance the progress made in steam-turbine development is that of the Capital Traction Co. of Washington, D. C., at Georgetown, with two

1,500-kilowatt, one 3,000-kilowatt, and one 5,000-kilowatt horizontal turbines. Although the smaller machines have been in use but a few years, such has been the progress in design that the 5,000-kilowatt turbine is not noticeably larger than the 3,000-kilowatt machine, or even the still smaller ones. The same condition has been shown in other plants using vertical turbines, where units of 20,000-kilowatt capacity now occupy little more floor space, except for the condensers, than did the 5,000-kilowatt machines of 10 years ago. The Georgetown plant is the result of the rapid outgrowing of former stations, and much of its equipment has been moved from them. This has, however, been so skillfully incorporated with the new apparatus that there is no evidence of patchwork.

On account of the gradual development of this plant a considerable variety of condensing equipment is found in it. The smallest turbines have jet condensers maintaining a 28-inch vacuum. A surface condenser on the 3,000-kilowatt unit holds a 29-inch vacuum, which is about the same as in the condenser of another type on the 5,000-kilowatt unit. The air and circulating pumps for the condensers are of the centrifugal type, but the boiler-feed pumps are reciprocating.

In the design of the building the architect has been very successful in producing a structure which, while it looks like a power station, would be an ornament anywhere but in a residential neighborhood. Much more attention is being given to the architecture of power plants than formerly, and it is fitting that in a vicinity containing so many handsome structures the railway power plant should be in keeping with its surroundings.

Louisville, Ky., generating plant.—A modern generating station, with an initial capacity of 12,000 kilowatts, which may be taken as one example of modern work, has been put in operation by the Louisville Traction Co., owner of the Louisville Railway and the Louisville & Interurban Railroad companies. This new station feeds the underground and overhead transmission system at 13,200 volts, 25 cycles, 3-phase, to two city substations, and to an old generating station which has been tied in with the new station, and in turn feeds six substations on the seven interurban lines radiating from Louisville. The unit system of design was followed in the construction of this new station, which will have an ultimate capacity of 48,000 kilowatts. The Louisville Railway and the Louisville & Interurban Railroad companies operate 165 miles of city track and 96 miles of interurban track, respectively. Prior to the completion of the new plant this system was supplied with electrical energy from the old plant situated on Beargrass Creek in the southeastern part of Louisville. This generating plant contained one 3,500-kilowatt and one 3,000-kilowatt steam turbine and two 1,650-kilowatt reciprocating vertical-engine-type units, all generating alternating current at 13,200 volts, 25 cycles, 3-phase. In addition to these, the old plant was equipped with two 1,650-kilowatt and three 500-kilowatt, 550-volt, direct-current generators, making a total of 14,600 kilowatts, alternating current and direct current, installed in connection with one 3,000-ampere-hour storage battery which was used as a reserve during peak-load periods.

Beargrass Creek, on which the old plant was situated and from which circulating water was obtained, received the discharge from a number of sewers. This did not materially impair the value of the water for use in the condensers, but a few years ago the city of Louisville constructed sewers parallel to the creek, and this resulted in reducing the flow of water to an almost negligible quantity. It thus became necessary for the railway company to seek a new supply of condensing water or a new site for a power station. It put off the day when it would be necessary to build a new plant and sunk artesian wells and installed a spray cooling system to furnish condensing water. These methods, with the limited amount of water supplied and the amount of pumping necessary, were costly and materially reduced the efficiency of the plant. To eliminate these difficulties and at the same time take advantage of modern generating efficiencies, it was decided to build a new station at a more advantageous location and especially where plenty of water was available.

In the meantime other difficulties arose which also tended to give impetus to the building of a new generating station. The average daily output in the existing plant increased from 35,000 kilowatt hours in 1900 to practically 150,000 kilowatt hours at the close of 1912. At the same time the maximum hourly load demand rose from 3,000 kilowatts in 1900 to 15,000 kilowatts in 1912. This rapid rise in the output was due to various causes, namely, increased car-mileage, track-mileage, car sizes, and car equipment. During 1902 the generating station output was 1.5 kilowatt hours per car-mile; in 1905 this had increased to 2.5 kilowatt hours, and in 1912 to approximately 3.9 kilowatt hours, per car-mile.

The factors entering into the location of the new plant were (1) ample condensing water supply, (2) ready access to steam railroad tracks for coal, and (3) cheap real estate for coal storage. To obtain these necessary requirements a site for the new plant was selected on the Ohio River. At a point in the river opposite Louisville the Federal Government has built a removable dam to limit the low-water stage in the Louisville Harbor. Rapids in the river opposite the city have also made necessary locks for transporting boats around the falls during low-river stages. Accordingly, property for the plant was purchased above the locks at a point where a definite minimum stage of the river could be obtained.

The new plant site fronts 1,358 feet on the Kentucky & Indiana Terminal Railroad Co.'s right of way, which adjoins the Louisville and Portland Canal. The transportation facilities offered at this location are especially desirable, because this railroad forms a part of a double-track belt line around about half the city and connects with all the steam roads entering Louisville. In addition, the general level of the plant property is approximately 5 feet above the maximum high-water stage of the river. The site is underlaid with bedrock at a depth of about 36 feet.

Switches at each end of the plant property connect with a long sidetrack paralleling the steam road's right of way. A lead from one end of this sidetrack in turn divides into five tracks, two of which lead over the coal hopper beside the boiler house, one into the boiler house, and one into the generating room under the crane. The space remaining between these four tracks furnishes sufficient area to store two or three months' coal supply in the open. This space has been graded, so that all surface water drains off readily. Approximately 30 cars of coal will be required every 24 hours for the completed station, and the yard layout of 4,000 feet of track provides for two days' supply of coal on cars at all times, with extra space for one day's empties.

The first section of the generating station includes a boiler room, 100 feet by 180 feet in plan, built with its long axis at right angles to that of the turbine room, which is 80 feet by 175 feet. This boiler room houses the initial equipment of eight 507-horsepower boilers, with spare space for a duplicate battery under the same roof. The turbine room was also designed large enough not only to house the initial installation of two 6,000-kilowatt steam turbines, but to provide space for the foundations of two additional units. The buildings are constructed of plain and reinforced concrete, brick and steel, and are thoroughly fireproof structures. They rest either on concrete caissons taken down to rock or on concrete mats resting on concrete piling driven to bedrock or to refusal. Ample provision is made for natural illumination and ventilation in the turbine and boiler rooms by large window-glass areas with steel sash. In addition, a double monitor skylight surmounts the firing aisle of the boiler room and the long axis of the turbine room.

For serving the initial installation of eight 507-horsepower water-tube boilers, a 13-foot by 255-foot dark red radial brick stack was erected on a concrete foundation resting on bedrock. This stack provides 1 square foot of cross-section for each 36.25 horsepower. The present boiler equipment generates steam at 200 pounds' pressure per square inch and 125° Fahrenheit superheat. Each unit is equipped with a chain-grate stoker having a grate 9 feet 6 inches wide by 12 feet 3 inches long. This size of grate was particularly designed to produce economical results with the Kentucky pea and slack coal used.

The stack rises to an elevation 253 feet above the grate level, and with six of the boilers in service the draft at the base of the stack has averaged 1.2 inches of water. Tests made over the front of the grates, the main breechings and the boiler dampers being open, showed pressure of 0.45 inch of water, while the draft at the last boiler pass measured 1 inch of water. A preliminary test of station efficiency during the second month's operation, before the steam piping was completely covered and while some steam was being used for drying-out and testing purposes, gave a coal consumption of 2.975 pounds per kilowatt hour, with 12.5 per cent ash. The coal used was western Kentucky pea and slack, containing approximately 12,000 heat units per pound when dry.

From the receiving track hoppers, 2-ton hand push cars convey the coal to the structural-steel bunkers over the boiler room by way of duplicate electric elevators. An industrial railway leads from the elevator shaft over the battery of bunkers, so that these cars may be pushed by hand and dumped at any point desired. The two platform elevators are of 6,000 pounds' capacity. They were designed to operate at 100 feet per minute, one being driven by a 550-volt, 30-horsepower, direct-current motor and the other by a 440-volt, 30-horsepower, 3-phase, alternating-current motor.

Each battery of two boilers is equipped with a coal bin holding 225 tons, which represents four and one-half days' fuel supply for ordinary operation. This large coal-bin capacity was deemed necessary as a precaution against shortage during extreme high-water periods when the tracks of the steam railroad might be inundated.

The ashes drop from the chain grates into two steel ash hoppers lined with fire brick and are dumped into push cars on an industrial railway. Siftings from the grates are dumped into the cars and returned to the coal bunkers. The small cars loaded with ashes are elevated to a steel ash hopper lined with fire brick, which is installed over the coal-unloading hoppers. By this arrangement, after the coal has been unloaded into the track hoppers the cars may again be loaded with ashes from the hoppers overhead.

The steam-pipe layout includes one steam header installed over the front of the boilers and at right angles to the turbine room. This header varies in size from 12 inches to 16 inches and is connected to a crossheader in the boiler room running parallel to the turbine room. Out of this crossheader steam is taken to the turbines by way of 12-inch long-radius bends. Two 10-inch long-radius bends take the steam to an auxiliary header in the basement of the turbine room, which in turn feeds all station auxiliaries. When the second row of boilers is installed a ring system of steam piping is contemplated which will encircle the boiler room so that any battery or any steam bend may be cut out of service for repairs without disturbing the other steam units.

Circulating water for the plant is taken from the canal through eight 4-foot 8-inch by 8-foot openings, the bottoms of which are approximately 50 feet below the generator-room floor, or 12 feet below normal water level in the canal. The tops of these intake openings are approximately 4 feet below normal water level, which, it is hoped, will prevent to a certain extent the clogging of the intake screens by floating trash. Just inside the intake openings in the canal walls there are cast-iron racks set at 20 degrees from the vertical and composed of 4-inch by 1½-inch bars with 2-inch openings between them for screening off logs and large trash. Manholes are provided over each of these racks in the intake structure, so that any trash collected may be hauled out with a long-handled fork.

A duplicate set of screens is installed in a screen house on the railway company's property, approximately 90 feet from the intake. At the screen house, which measures 18 feet 6 inches by 30 feet 4 inches in plan, the intakes flare to provide supports for stop planks and a double row of movable vertical screens. The latter have been installed with four double screens in each of the four channels. The sizes of the openings for both intake and discharge were figured for a flow of 160,000 gallons per minute, or 20,000 gallons per minute for each of the eight units in the initial station installation. At this rate of flow, the openings produce a discharge speed of only 1.19 feet per second, such a reduction having been necessary in order not to interfere with small boats passing in the canal.

Two 30-inch cast-iron pipes are laid over the outside walls of each intake conduit. These pipes are continuous from taps in the discharge-water conduit to the inlet at the canal end of the intake and were provided to protect the intakes from clogging with needle ice. Valves installed in these cast-iron connections may be opened and hot water discharged into the canal at the mouth of the intakes. As the hot water is taken from the discharge conduit, the only expense involved is that of maintaining the pipe line from the turbine room to the intake structure at the canal.

The turbine room and its basement for the auxiliaries measure 174 feet long by 61 feet 6.5 inches wide, with four galleries on one side, 21 feet 10.5 inches in width. The turbine room is served by a 50-ton crane. Each turbine foundation consists of two parallel walls resting on bedrock and extending to within 18 inches of the main turbine-floor level. These walls are so placed and spaced that the surface condensers may be dropped in place under the turbines by the overhead crane. The turbine proper rests on an I-beam grillage, supported in turn on the two concrete foundation walls. Special attention was given to the design and installation of these turbine concrete foundations, in view of the fact that their bases are below water level in the river.

The circulating pumps are installed 45 feet below maximum high water and only 1 foot above the low-water stage of the Ohio River. This has made it necessary to seal all pipes into the concrete conduit to prevent flooding during high water, when all the waterways inside the building are under very great pressure.

Each of the 6,000-kilowatt horizontal steam turbo-generators is equipped with a 20,000-square-foot surface condenser. Circulating water is supplied to each condenser by a 26-inch tri-rotor centrifugal pump, driven by a steam turbine. Each has an emergency 30-inch pipe connection to the circulating pump of the other turbine. The units are arranged in pairs with condensing auxiliaries in a pit between the two foundations. Thus the first two units are spaced 45 feet apart and the second and third units are 30 feet apart. In this way one operator can care for the auxiliaries of two units. This arrangement also permits sets to be cross connected more readily and economically. The dry-vacuum pumps, the main circulating pumps, and the hot-well pumps are connected and arranged so that either generating unit may be used with either of the auxiliaries. A 4-inch, two-stage hot-well pump driven by a 27-horsepower steam turbine completes the steam-turbine equipment.

The turbo-generators deliver 13,000-volt, 25-cycle, 3-phase energy, which is transmitted over the feeder lines at this same bus pressure. Regulators control the voltage of the main alternators, the excitation energy for which is supplied by a 30-kilowatt motor-driven direct-current set and by one 100-kilowatt and one 150-kilowatt steam-turbine-driven exciter set.

The first 2,000-kilowatt rotary converter has been installed on one of the foundations provided for it beside the auxiliary pit, and feeds the trolley sections in the vicinity of the new generating station. This substation equipment is tied in with the two city substations by way of a 600-volt direct-current trunk line. This installation required three 750-kilowatt, single-phase, oil-cooled, step-down transformers rated at 13,200/440 volts.

A four-level gallery adjoins one side of the turbine room. On the lowest level, which is below the turbine-room floor, the conduit carrying the underground transmission cables is brought in from the street. From the conduit the cables radiate through the necessary cable-end bells, supported from a central concrete wall which also carries the transformer compartment. This compartment extends the full length of the turbine room and is completely separated from the basement under the turbine-room floor by a 13-inch brick curtain wall. All openings between this gallery and the turbine room are fitted with doors, so that the space may be entirely closed and used as an air chamber to supply air to the turbines. An air intake is provided outside of the station at one end of this lower gallery, and air is taken into this chamber by way of louvered openings. After the air passes through the intake into this lower gallery it is screened through one-fourth-inch mesh copper screens covered with cheesecloth and set at 30° to the direction of the air current.

A machine shop is situated on the main-floor gallery along with the tool room and store rooms and the oil switches controlling the high-tension generator and feeder circuits. These 13,200-volt switches are installed in the concrete switch and bus structure, which is built in two parallel sections. At the present time these two sections are divided at their mid-point, so that there are four sections of the high-tension bus. The bus and feeder arrangement is such that each section of the bus connects one generator and four feeder switches. Each generator has two oil switches in series, while each feeder is provided with a single oil switch. Disconnecting switches are provided in each phase and on both sides of each oil switch so any one may be cut out of service for repairs or cleaning.

The complete high-tension bus structure was built for 4 generating units and 16 feeders. The structure itself has been erected for the complete station. All generator switches are nonautomatic, and the feeder oil switches and junction bus section switches are automatic and provided with inverse time-limit relays.

Large turbo-generator units.—The turbines for the Interborough Rapid Transit Co. of New York, exemplifying some of the latest advances in steam use for electrical energy generation, are unusual, not only for their size but also because of the fact that each set is made up of two units, one operating with high-pressure steam at 1,500 revolutions per minute and the other receiving the exhaust from the former and running at 750 revolutions per minute. Each set has a combined capacity of 30,000 kilowatts, but owing to the enormous amounts of power required by the whole system the new units can be operated at the most economical load during the major part of the time, and therefore they were designed to give the very highest obtainable efficiency, nearly regardless of their cost—the only essential superior to this desideratum being reliability in operation.

Turbines of 30,000-kilowatt capacity may be designed in single units, operating at 750 revolutions per minute. Such machines would be relatively economical and would probably show a steam-consumption performance higher than has hitherto been obtained. The turbine cylinder structure, however, on account of the slow rotative speed, would be relatively large, and this, together with the temperature differences existing within the one structure, would involve in a machine of such large capacity an engineering problem of some magnitude. Similarly, both steam turbine and generator of this capacity might be designed and constructed to operate at 1,500 revolutions per minute. In this case the structure would be less gigantic, but in order to avoid congestion of the steam in the low-pressure portions of the turbine, and to permit it to expand efficiently down to the very low limits of condenser pressure, 29-inch vacuum in this instance, blade speeds rather beyond what has hitherto been considered the limit of good practice would be involved. Either of these would be a combination type machine, comprising an impulse element for the first expansion, followed by an appropriate number of reaction elements for the low-pressure stages, the latter being arranged for double flow.

The highest degree of economy, however, is not to be obtained with an impulse element, as compared with a reaction element, provided the steam volumes, speed, etc., are appropriate for the design of the reaction turbine; but in any reaction turbine designed for high-expansion ratios the problem of having to deal with relatively minute volumes of steam at the high-pressure end and enormous volumes at the low-pressure end is serious, the increase of volume being roughly on the order of a geometric progression. It is evident that if the high-pressure portions of a turbine may be operated at twice the rotative speed of the low-pressure portions, this problem is largely eliminated, and the capacities and speeds in this particular application, where the high pressure is a single-flow turbine, operating at 1,500 revolutions per minute, and the low pressure is a double-flow turbine, operating at 750 revolutions per minute, point to the possibility of designing plain reaction machines which will have an efficiency beyond anything yet constructed. The blade speeds involved are low, and either turbine element is of exceedingly simple mechanical construction, involving no new engineering problems and thoroughly fulfilling the first desideratum of absolute reliability.

The scheme of employing two turbine elements having the steam pass serially through them is not new. A number of such units of from 1,000-kilowatt to 2,000-kilowatt capacity were built in 1901. This construction has again come to the front in the case of the English-built turbines for the Commonwealth Edison Co. of Chicago. It is new, however, to employ high-pressure and low-pressure elements driving separate generators, each at a different synchronous speed.

There are other advantages in dividing large turbines into two separate elements besides those due to employing different speeds. The temperature range in either element is reduced. A sufficient number of stages may be introduced to give the very highest efficiency without any mechanical difficulties, such as increased length between bearings, etc. Some little advantage is to be gained by separating between the two turbine elements the water which has been precipitated in the steam expansion. Either element is more reliable and simple, because of its smaller size. There is some slight loss of efficiency due to the employment of two generators instead of one of twice the capacity, but this is more than overbalanced by the gain in economy due to the operation of the two turbine elements at different speeds. It is guaranteed that each set will deliver energy at the terminals of the generator equivalent to 75¾ per cent of that available in the steam.

Interurban light and railway plant.—A tendency toward the occupancy of a broader field of service has been shown among interurban electric railways. The Cleveland, Painesville & Eastern Railroad, for example, has adopted the policy of entering the lighting field in the towns traversed by its lines, as the company believes that the benefits gained by the recent consolidation of its plants in the railway field may be extended to the other branches of public service. The town of Willoughby, Ohio, where the company's headquarters are located, has a municipally owned plant and current is bought by it from the railway company at the switchboard. Power in large quantities, however, is sold directly to users by the railway company. From Willoughby, lighting lines are extended to Wickliffe on the west and Mentor on the east. From a substation in Painesville are fed the towns of Perry, Richmond, and Fairport, and the Geneva substation supplies Madison, Unionville, and Saybrook, the average run being about 8 miles on each side of the generating plant or substation. The company has secured lighting loads of over 250 kilowatts in the towns of Willoughby and Mentor, and this without making any extensive campaign for the business. It is contracting with several municipalities to pump their water supply. The rate charged for lighting is 11 cents per kilowatt hour, less 2 cents discount if paid on or before the tenth of the month. Power rates are based on a sliding scale, depending on the load factor. They vary from 5 cents per kilowatt hour to 1¾ cents per kilowatt hour, with a guaranteed minimum of $1 per month per horsepower of connected load. Another schedule in force makes use of a maximum demand meter, with the same rates for installations over 50 horsepower in capacity, in which case the customer furnishes the transformer equipment and buys energy on the high-tension side at 2,200 volts. The entire railway traverses a well populated, fertile country, abounding in agricultural and dairy products and having great natural beauty. About 40,000 people are located in the territory served by the line.

The power house is located in the town of Painesville, Ohio, on the bank of Grand River. It consists of a main building approximately 97 feet by 105 feet and an annex 42 feet by 21 feet. The chimney is of radial brick, 200 feet in height and 13 feet in inside diameter, built to take care of an ample increase in boiler capacity. Coal is obtained over the tracks of the Lake Shore & Michigan Southern Railroad, and the method of handling it is one of the unique features of the station. A steel hopper with a capacity of 500 tons which receives coal direct from railroad cars is built into the trestle over which pass the tracks of the electric railway. The railroad car containing the coal is taken out on the trestle between the scheduled time for the interurban cars by a home-made electric locomotive, and the coal is dumped direct into the hopper, the entire unloading being accomplished in a period of about 10 minutes. The hopper has sufficient capacity for approximately 10 days' supply. The locomotive is weighted down with steel punchings from the shop and is equipped with two 50-horsepower motors and automatic air brakes. It will haul two gondola cars of coal at each trip and obviates the necessity of sending a work car and its crew from the car house at Willoughby whenever it is desired to unload coal. From the hopper the coal descends by gravity into cars on a track beneath. These run into the boiler room upon an elevated track located above the stoker hoppers, and the coal is dropped into the stokers as required. The average consumption is about 40 tons a day.

The ashes drop into brick-lined steel hoppers equipped with gate valves of the same type as those used for the coal. The ash tunnel is located directly under the furnaces, and ash cars run from there to an elevator, where they are hoisted to an outside track. The ashes are used for filling in the low ground adjacent to the power house. The ash cars are interchangeable with those used for hauling the coal.

The boiler plant consists of three batteries of two 166-horsepower boilers each, aggregating 2,200 horsepower in actual capacity.

Cooling water for the surface condensers is taken from the Grand River, and the siphon circulating system used possesses some novel features. A pump house is located on the bank of the river, approximately 350 feet from the power house. It is of brick, 26 feet by 17, and, owing to its proximity to the river, it was found impossible to secure even a clay foundation on which to build it. Consequently, it was constructed in the form of a reinforced concrete basket set on concrete piling.

In order to secure an uninterrupted supply of circulating water, free from all débris, a concrete intake box having two sets of screens was sunk near the edge of the main channel of the river. The upper portion of the box is covered with a perforated caisson built of boiler plate and having a screen bolted to the top, so that, even when flood waters completely cover the intake, clean water can be secured. The intake box is connected with a 24-foot storage well just outside of the pump house by a 48-inch tiling some 80 feet in length. The water before entering the well passes through another box equipped with double screens, and it has been found that an ample supply of clean water is assured without the use of the twin strainers or similar appliances usually introduced in circulating lines.

The pumping equipment consists of two 14-inch centrifugal pumps, each having a capacity of 500 gallons per minute and driven by a 50-horsepower, 440-volt, induction motor. These motors are controlled entirely from the power house, although air-break switches are installed at the pump house for use in case of emergency. It is unnecessary, therefore, for anyone to visit the pump house except for purposes of inspection.

Each pump has a separate suction pipe to the well, but they both discharge into a single 20-inch main leading to the power house. The various condensers receive water from this single main and discharge it into another single 20-inch main, which leads back to the river, making a complete siphon system. These pipes are of cast iron, having flanged joints, and they are laid in a 6-foot concrete tunnel extending from the power house to within 75 feet of the pump house. Gate valves operated from the turbine floor control the supply and discharge lines to each condenser, so that any condenser may be taken off the line for purposes of inspection or repair without breaking the siphon effect of the circulating system. At the same time these permit regulation of the amount of water used in the condensers under various operating conditions. A combination wet and dry pump is installed to start the system if for any reason it should become empty of water. The discharge pipe to the river is provided with a Y connection to insure a supply of warm water in order to get rid of any needle ice which may gather at the intake in the winter.

Owing to the fact that the system embraces a siphon, the motor-driven pumps have only to overcome the friction of the complete circulating system, thus calling for considerably less expenditure of energy than if they had to work against the entire head. A steam-driven centrifugal pump is also installed at the pump house for cleaning out the well, and a telephone line between the pump house and the power house affords a ready means of communication when anyone has occasion to visit the pump house for the purpose of inspection.

All of the valves used in connection with the engines, turbines, and condenser equipment are controlled from the engine-room floor, so that the engineer does not have to leave the floor, but can control all machinery therefrom.

Great importance is attached to the value of tests, and one is being run all the time to ascertain just what is being done and what results are secured. Accurate records are kept of coal, water, and ash, so that the operating efficiency can be computed at any time. A water meter accurately measures the boiler-feed water, the ashes are weighed; and the percentage of ash in the coal is obtained. The total operating force consists of 11 men, working in two 12-hour shifts.

The scheme of painting the piping around the station in different colors facilitates greatly the work of the employees, as one can tell at a glance just what the pipe is carrying. Live steam is indicated by green, exhaust steam by brown, hot water by red, cold water by black. The engine-room walls are painted white, with a green border.

The generating equipment consisted formerly of two 360-kilovolt-ampere, 25-cycle generators, direct connected to two 18-inch by 36-inch by 42-inch engines delivering current at 6,600 volts. The natural increase in load, however, and that due to extensions and other business secured, required additional station capacity, and the following apparatus was installed in 1912: Two 1,670-kilovolt-ampere, 25-cycle, 6,600-volt turbo-generators operating at 1,500 revolutions per minute, and two 50-kilowatt, 125-volt turbo-exciter sets, together with a 22-panel switchboard.

The switchboard is located on a raised portion of the floor overlooking the remainder of the engine room. A swinging bracket at the end contains two voltmeters, a frequency meter, and a synchroscope. Each generator panel is equipped with an ammeter, a voltmeter, power-factor meter, watt-hour meter, field rheostats, and nonautomatic oil switches. The high-tension feeder panels are equipped each with three ammeters, a watt-hour meter, an automatic oil switch, and relays. Four panels are devoted to the control of the exciters, with the usual equipment of ammeters, voltmeters, rheostats, and knife switches.

A substation, consisting of two 360-kilovolt-ampere, 600-volt, direct-current rotary converters and a portion of the main switchboard devoted to their control, is located in the power house. The main transformers are arranged in two banks, each having three 500-kilovolt-ampere units, located in the basement. They step up the voltage from 6,600 to 13,200 for transmission to the other substations at Willoughby, Geneva, and Ashtabula. It has been proposed, however, to raise the transmission voltage to 22,000.

Evolution of Minneapolis plant.—The evolution of the steampower plant of the Twin City Rapid Transit Company in Minneapolis is a good example of the rapid changes which have taken place generally in the methods of power production in the street railway field. Originally this plant contained triple-expansion Corliss engines, representing the best practice of 20 years ago, and these engines were connected through jack shafts to 150-horsepower generators, large for the time. This equipment produced electrical energy at high cost for fuel, because the nature of the load did not permit the engines to be used under good operating conditions, and also at high cost for maintenance, on account of the complicated character of the machinery. Ten years ago a modern steam plant was designed to contain ultimately five vertical cross-compound reciprocating engines of 5,000-horsepower capacity, direct-connected to 3-phase, 13,200-volt, 35-cycle generators rated at 3,500-kilowatt capacity, or at, say, 4,000 kilowatts on the now standard temperature rise. Three of these engines were installed by 1905, giving the plant an actual capacity of 12,000 kilowatts. The engines were supplied from a boiler room containing 18 standard water-tube boilers with 5,560 square feet of heating surface each, giving a nominal rating of 556 horsepower. These were equipped with stokers of a continuous capacity of 825 boiler horsepower to produce a 50 per cent overload output of the boilers. The boilers contained superheaters of a capacity to produce 120 degrees superheat at rated load. Draft was furnished by two radial-brick stacks, 162 feet high, mounted on masonry 63 feet above the boiler-room floor. The flue diameter was 16 feet. Two flues, each of 125 square feet cross-section, connected the boiler uptakes with each stack.

Following the original plan, a fourth engine and eight more boilers were added in April, 1906. By this time, however, the steam turbine had entered the field; and instead of the fifth reciprocating engine, two 5,000-kilowatt vertical turbines were installed in February and July, 1907, respectively, in the place provided for it. The fact that this space accommodated turbines with three times the capacity of the engines which could have been installed therein is significant. No increase in boiler capacity was made. The plant was typical of the best practice of the time. Hardly had the new turbines been installed, however, when it was found possible to secure larger and more economical ones, and the process of replacing the engine units began. In the meantime experiments had been made with chain-grate stokers, and in January, 1909, two, in July four more, and during the fall six more, were installed. By this time the stack capacity was greatly overtaxed, and one of the brick stacks was replaced, in November, 1910, by two brick-lined steel stacks, with internal diameters of 14 feet, mounted on structural-steel frames over the boilers. Their tops were 265 feet above the boiler-room floor. A 4,000-kilowatt vertical steam-turbine unit was put into service in February, 1911, and in July six more chain grates were installed. Two more boilers, of 5,000 square feet heating surface, were added in the space formerly occupied by masonry stack foundations, and the remaining furnaces were equipped with chain grates. Again the stacks were overtaxed, and the second brick one was replaced with two steel ones in August, 1912. During the following month a 15,000-kilowatt turbine set displaced the second engine. More steam being required, two more boilers were added in January, 1913, in the space formerly occupied by the second brick stack. The installation of a third large turbine, also of 15,000-kilowatt capacity, was completed in 1913, and but one engine of the original four of 1906 remained in service. The story of advance and obsolescence was practically complete.

Combination steam and hydraulic plant.—The Northern Ohio Traction & Light Co.'s plant of 1913 illustrates the combination of steam and hydroelectric service in one system for the supply of electrical energy. It includes a steam station with a present rating of 20,000 kilowatts and an ultimate rating of 50,000 kilowatts, a hydroelectric station of 2,000-kilowatt rating, eight substations, and the necessary transmission lines. The company owns and operates approximately 216 miles of single track, consisting of the city lines in Akron and Canton and the interurban lines from Akron north to Cleveland, south to Canton, Massillon, Urichsville, Canal Dover, etc., east to Kent and Ravenna, and southwest to Barberton and Wadsworth. In addition, it supplies electricity for all services in the city of Akron and numerous towns and villages on the railway lines. The latter business has developed more rapidly during the past few years than the company's facilities for handling it, and in several instances the proffered business has necessarily been refused. The gross receipts of the company during 1912 exceeded those of 1911 by 11.2 per cent.

The company's Gorge power station, supplemented by the hydroelectric station, replaces stations at Akron, Silver Lake Junction, and Bedford, and furnishes all energy required north of Canton. The existing stations at Canton, generating alternating current at 25 cycles, however, continue to supply the city lines in Canton and the interurban lines south of Canton. The Gorge station is located in the valley of the Cuyahoga River, just below the Cuyahoga Falls, Ohio. As the low-water flow of the Cuyahoga River was not sufficient for condensing purposes, it was necessary to build a dam so that a suitable pond for cooling water would be provided; and as the fall of the Cuyahoga River is quite rapid at this point, it was found possible, by utilizing the head from this dam in connection with a fall below the dam, to secure a head of about 100 feet one-half mile below the dam.

The coal for the station is delivered over the Pennsylvania Railroad, the only railroad near the site. The company has a siding from this road which runs along the top of the river bank at an elevation about 90 feet above the boiler-room floor. A trestle with coal bunkers underneath allows loaded cars to be shifted by the company's motor car. From the bunkers the coal passes through valves into the crusher and through this crusher into individual bunkers for the boilers.

The power station proper consists of the boiler room, 56 feet wide by 330 feet long, and the turbine room, 63 feet wide by 227 feet long, separated by a division wall, the turbine room being on the river side. The turbine room was located on this side in order to decrease the length of the condensing-water tunnels and also to simplify the delivery of coal to the boiler room. In addition, there are two small wings, in one of which are the blowers for the forced draft and in the other are the lightning arresters.

The main floor of the boiler room, which is flush with the basement of the turbine room, is placed at elevation 918.5 (above sea level), which is about 40 feet above the head of the stream and about 90 feet below the top of the bluff, where coal is delivered. The dam, which is about half a mile below this station, has its spillway at elevation 910, so that low water would only be 8 feet 6 inches below the turbine-room basement. During the famous 1913 floods in Ohio the water rose to elevation 918.2.

The boiler room contains sixteen 604-horsepower tubular boilers and superheaters, arranged in a single row, the stack being placed in the center of the boiler room, with eight boilers on one side and eight on the other. All boilers are equipped with stokers. Fans, located in the blower room, just south of the boiler room, furnish the forced draft for these stokers. The ashes are dumped into ash pockets underneath the grates and thence into a small car running on a track in the basement.

Steam at a pressure of 200 pounds is used with a superheat from 75° to 90°. Each boiler is equipped with recording instruments in order that a complete comparative record of coal consumption and steam furnished may be kept. The radial-brick stack is 275 feet high. The stack is unusually high because the station is about 90 feet below the surrounding country. There are two openings for the breeching, each 20 feet high and 7.5 feet wide. The novelty in its construction was the use of ¼-inch American ingot iron plates.

The main steam header has been so arranged that the boilers may be divided into four groups, one or more of which may be out of service at any time. All nozzles were welded on by an electric arc.

The main steam piping consists of a 12-inch header in the boiler room, connected to the boilers by 8-inch compound bends. This header is connected to the three turbines by 12-inch leads, each of which is provided with a suitable separator at the lowest point and an angle valve adjacent to the throttle valve. This arrangement allows the separator to drain the header at all times, whether the turbine is in service or not. There is an 8-inch auxiliary header in the turbine-room basement, connected to this 12-inch header at three points, from which all connections are taken to auxiliaries.

A 50,000-gallon steel tank set on the bluff just above the station, with a head of about 100 feet, supplies the general service water, the cooling water for transformers, the water lines for cooling ashes, and the fire lines.

Air piping has been carried throughout the building, as compressed air is used in cleaning the generators, rotaries, etc., in the turbine room, and for operating turbine tube cleaners in the boiler room.

The oil piping for the transformers is so arranged that the oil from any transformer may be removed through pipe to barrels which are set in a pit at one end of the pipe line; or, in case of fire, this oil can be run to a pit outside of the building.

The installation of generating equipment consists of three 6,300-kilowatt, 2,300-volt, 60-cycle, 3-phase turbo-generators, 1,800 revolutions per minute, directly connected to three horizontal double-flow steam turbines, with a guaranteed steam consumption not to exceed 14.8 pounds per kilowatt hour at 100 per cent of rating and 15.4 pounds at 150 per cent. Space has been provided for two additional similar or larger units in the future. Two 150-kilowatt steam-driven exciters have been installed with an extra motor-driven unit. These exciters are placed on the turbine-room floor between main units and directly in front of the main switchboard.

The exhaust from the turbines discharges into steam condensers, which are in the basement, immediately underneath the turbines. The circulating and air pumps for these condensers are on a single shaft and are driven by a 228-horsepower steam turbine. As there was a possibility that at some time the level of the pond would be drawn below the spillway of the dam, single-stage booster pumps were provided in the turbine-room basement, near the condensers, driven by 75-horsepower, 2,300-volt, 3-phase motors.

Three boiler-feed pumps driven by steam turbines have been provided in the basement of the turbine room. The pumps normally take their water from three feed-water heaters placed on a platform midway between the turbine-room floor and the basement floor. The feed-water heaters are filled from the hot-well or discharge tunnel by means of two pumps directly connected to motors. Two service pumps directly connected to motors, each having a rating of 150 gallons per minute, are also located in the basement. These pumps are used in filling the service tank on the bluff.

The electrical operation of the station is controlled from a gallery about 40 feet long on the river side of the turbine room. A bench board on this gallery contains 14 panels. Three of these are used for the control of the main units, two for the exciters, three for outgoing high-tension lines, three for 2,300-volt lines to substation No. 3, one for 2,300-volt lines to the booster-pump motors, and two are blank for future connections. Indicating and recording instruments are on vertical panels above the bench board.

The structure for the busbars and oil switches is on the main floor under the front of this gallery. The ends of this structure are inclosed, forming a room in which the high-tension circuit-breakers are installed. The main cables from the generators are carried under the turbine-room floor to the 2,300-volt busbar. From this bus cables lead to three 3,000-kilowatt transformers. The transformers are located in the turbine-room basement directly beneath the switchboard gallery and step up to 22,000 volts for the outgoing high-tension lines which feed the substations mentioned before. The high-tension cables pass through ducts in the turbine-room floor to the lightning-arrester room. In this room are installed three sets of electrolytic lightning arresters. Directly above this room is a transmission tower which is the starting point for all lines. Substation No. 3 is located in the northwest corner of the turbine room and consists of three 500-kilowatt, 6-phase, 60-cycle rotaries and three step-down transformers, which are fed directly from the 2,300-volt main busbar. The switchboard for this substation contains the necessary panels for the rotaries and outgoing feeders. Sixty-cycle rotaries were finally selected for this service to avoid frequency changes, in view of the fact that remarkable progress has been made during the past few years in their design. Additional panels for switches and circuit-breakers for lighting and auxiliary motors are placed on the turbine-room floor near the substation board.

Combination railway, lighting, and ice plant.—There are some instances where the steam generator plant of a street railway, besides being available for traction, lighting, and industrial motors, has been applied directly or through an intermediary to ice-making, especially in the South. The Louisville, Ky., plant may be cited as one example. Another illustration is the plant of the Newport News & Old Point Railway and Electric Co., where the reconstruction of the engine equipment, introducing turbo-generators, has carried with it improvements in the ice-making apparatus. The ice plant, adjacent to the power house, had a rated capacity of 100 tons of ice and contained two ammonia compressors, one a 40-ton, 14-inch by 28-inch tandem-compound condensing machine, and the other a 60-ton, 16-inch by 24-inch tandem-compound condensing machine. The 40-ton freezing tank had fallen into disuse, and, owing to inadequate auxiliaries, both compressors were operated on the 60-ton tank during hot weather without getting full capacity. The plant has now been completely overhauled, and recent records show that with an outside temperature of 100° in the shade a regular output of 105 tons of ice per day can be maintained aside from the refrigeration of storage rooms, estimated as equivalent to 3 tons or 4 tons of ice production. The new atmospheric ammonia condensers were constructed out of the old atmospheric condenser of the 40-ton equipment by adding ejectors and sprinkling troughs. The stands are 20 feet long and are made up of 2-inch pipes 12 pipes high. Seven stands were erected for the 60-ton and five stands for the 40-ton compressor. Each stand takes approximately 60 gallons of water per minute. The coolers are of construction similar to that of the condensers, but are made of standard-weight galvanized-iron pipe, and consist of three stands for the 40-ton equipment. These are supplied from the same water and pumps as the condensers, but use only 30 gallons per minute per stand.

The 40-ton freezing tank, containing 12,880 feet of 1½-inch pipe and 596 300-pound cans, which was formerly operated on the dry-gas system, has been changed to a wet-gas system by installing a 30-inch by 8-foot accumulator set down in the tank. A 6-inch space underneath the tank was filled with fine regranulated cork by blowing it in with compressed air and thoroughly sealing it with waterproof paper and hard pine. The sides, which were formerly of wood and were badly decayed, were replaced by walls of hollow tiles and 8 inches of regranulated cork. The 60-ton freezing tank, containing 12,036 feet of 1¼-inch pipe and 720 300-pound cans arranged for the flooded system, was changed to a wet-gas system by the addition of two 20-inch by 8-foot accumulators. New handling rooms of 450 square feet and 750 square feet, respectively, were prepared for the 40-ton and 60-ton tanks, and these, together with two storage rooms of 680 tons capacity, are refrigerated by direct expansion.

The storage tanks are cooled by direct expansion and not by passing the return gas from the freezing tanks through the coils. Each tank contains 300 feet of 2-inch pipe, and the water leaves these tanks at 40° Fahrenheit for the freezing cans.

HYDROELECTRIC DEVELOPMENT.

There are not many examples of huge hydroelectric development intended solely for the utilization of their electrical energy in street railway work, or even in the electrification of steam railroads; but on the other hand there are very few, if any, electric power-transmission systems without a railway "load." Thus the plant of the Mississippi River Power Co.,[1] at Keokuk, Iowa, with an initial capacity of 108,000 kilowatts, transmits energy at 110,000 volts 140 miles to St. Louis for street railway operation; and the 54,500-kilowatt plant of the Pennsylvania Water & Power Co. on the Susquehanna River at Holtwood, Pa.,[2] transmits energy at 70,000 volts 40 miles to Baltimore to provide a part of the power for operating the street cars of that city. The circuits of the Pacific Gas & Electric Co. ramify over more than half the state of California, and a large proportion of the current generated at its plants and fed into the circuits is employed in transportation.

Tallulah Falls, Ga., water power.—The Georgia Railway & Power Co., of Atlanta, Ga., has built an unusually large hydroelectric system at a point on the Tallulah River known as Tallulah Falls, the region and locality being one of the most famous summer-holiday resorts of the South. This is the only large development at high head east of the Mississippi, if one excepts

[1] See p. 99, Central Electric Light and Power Stations, for full description of this plant.
[2] See p. 98, ibid.

Niagara, where the head is only one-third as high. Six hundred feet of fall is unusual anywhere, and to find a large installation working at this head in the southern Appalachian country is impressive. The present installation consists of five 17,000-horsepower turbines, each connected to a 10,000-kilowatt generator. The general construction of the system is typical of the development of high heads, except that advantage was taken of the topographical conditions to build a 110-foot dam above the natural falls of the stream. Below the dam is a tunnel cut-off, nearly a mile and a quarter long, through solid rock, terminating in an artificial forebay of concrete and steel, from which drop five 60-inch penstocks, a little over 1,000 feet long, to the wheels below. Another interesting feature of the plant is the storage pond and its appurtenances. The reservoir is about 6 miles above the head works, where a 90-foot dam has been thrown across the stream, impounding more than 1,000,000,000 cubic feet of water. This pond renders available, when it is drawn upon, a considerable power, and the plans include an auxiliary plant at this point containing two 3,000-kilowatt units to utilize the water drawn from storage and transmit the energy to the main line below. At the main dam, provision has been made for keeping the head constant during floods by the installation of automatic swinging flashboards controlled by counterweights so as to hold the elevation of the pond back of the dam practically constant.

The generators are on vertical shafts with the weight carried in suspension from oil-pressure bearings at the upper ends of the shafts. There are five 17,000-horsepower turbines, each direct connected to a 10,000-kilowatt generator. Energy is transmitted over a steel-tower, copper-line circuit at 110,000 volts to substations at Atlanta, Newnan, Lindale, Gainesville, and Cartersville, all of the modern outdoor type, the Atlanta receiving substation being the largest of the kind anywhere in the world. It is close to the city limits, with a present rating of 30,000 kilowatts and an ultimate of 60,000 kilowatts in 110,000/11,000-volt transformer equipment. The distance from the falls to Atlanta, which has a large trolley street-car system thus served, is 87.5 miles.

Bull Run plant of Portland, Oreg.—A recent typical plant on the Pacific Northwest coast is that of the Portland Railway Light & Power Co. in the rocky gorges of the Bull Run River, 28 miles from Portland. The plant derives its energy from the two confluents of that river, the Little and Big Sandy, which, together with the Bull Run itself, drain an area of approximately 521 square miles.[1] The drainage basin extends away up into the Oregon Forest Reserve, and in the case of the Big Sandy, to the melting snow and ice of the glaciers on Mount Hood. The Sandy and its tributaries drain the western slope of the Cascade Mountains in the northern part of Oregon.

The Bull Run River supplies Portland with its drinking water. A Government reserve, which carries the name of the river, was created by Congress as a protection for the city's water supply. Two steel pipes, 54 inches and 42 inches in diameter, carry the clear, cold water of the Bull Run to Portland. Although the power plant is on the banks of the Bull Run, the water necessary to operate it comes from the Little Sandy, a branch of the Bull Run, and the Big Sandy, about 7 miles above its junction with the Bull Run. As the Little Sandy could only furnish a small percentage of the total amount of water needed during the low-water months, a "hogback" mountain, known as the "Devil's Backbone," was pierced, and from the portal of this tunnel opening on the Big Sandy side a flume 12 feet by 8 feet 6 inches, approximately 1.42 miles long, connects with a 32-foot-high, 300-foot-long, timber-crib, rock-filled dam, set in concrete abutments. The headworks of the intake to the flume at this dam consist of two timber gates, 5 feet by 10 feet, set in the abutment section. The main tunnel is about 4,700 feet long, 10 feet 11 inches by 10 feet 8 inches, lined with timber, and opens up on the Little Sandy side above a diversion dam of concrete, 13 feet high and 114 feet long, 17½ feet thick through apron, and 18 inches wide at top. Thence the water is carried through a 9-foot 6-inch by 6-foot 10-inch flume, 3.25 miles long, to the forebay or reservoir of 1½ acres. In this reservoir are three concrete intakes to the 9-foot penstocks that supply water to the turbines in the power house 325 feet below. The reservoir site is to a large extent a natural one, but in order to increase its storage facilities an earth-rock, riprap-faced dike was erected around two sides of it. The storage available here is sufficient for 48 hours' operation of the plant in case of an accident to the flume.

The 9-foot penstocks are 1,400 feet long, and for the first 475 feet of their length run in tunnels under the reservoir. Just outside the portals of these tunnels, standpipes 5 feet in diameter and 42 feet high, topped with surge tanks 15 feet in diameter and 15 feet high, are riveted to the penstocks to take care of any vacuum stresses, surging, or water-hammer action that might be set up, due to opening or closing of the huge butterfly valves located in the concrete intakes in the reservoir or to the sudden taking off of the load on the generators in the power house.

The penstocks run in trenches, with concrete anchors located at frequent intervals. About 140 feet from the power house, each 9-foot penstock branches into two, 6½ feet in diameter, each feeding a water wheel.

Provision has been made for four units, and three are installed. Each of the two 6,400-horsepower, 514-revolutions-per-minute wheels consists of a single 42-inch wheel mounted on a horizontal shaft and arranged to discharge into a cast-iron quarter-turn. The wheel is inclosed in a cast-iron spiral flume casing, the neck end of which is 54 inches in diameter. The gates

[1] Electric Traction, July, 1913, Vol. IX, No. 7.

through which the water is discharged into the buckets are of the wicket or spring pattern type, so designed that the head of water on the wheels is always tending to close them. As these turbines are of single-runner type, it was necessary to take care of end thrust. This was overcome by means of a water-step bearing in the neck of the quarter-turn, of sufficient diameter to take the full end thrust of the wheel when working under operating head. The water for this thrust bearing comes from the penstocks supplying the wheels, but is cleansed by being forced through a strainer so arranged that it can be cleaned without having to be dismantled. In addition to the hydraulic method of taking care of the end thrust, there is also installed an oil collar bearing. On the outside of the oil chambers a water jacket is installed to prevent the oil from heating. The governors are of the vertical type, with oil pump and pressure tank. The pump is driven from the shaft of the water wheel by means of a belt. It is possible to obtain regulation as close as 6 per cent. The governor is driven by a silent chain and can be controlled electrically from the switchboard.

The other turbine wheel is what is known as the scroll case, single-runner, horizontal-shaft type, guaranteed to deliver 6,000 brake horsepower at 514 revolutions per minute under 320-foot head. The operating mechanism of the gates is of the wicket type and so balanced that under ordinary operating conditions they do not require a very large force to open or close them. They can be operated by hand with the oil-pressure governor. The case covering the runner is of cast iron, of a spiral form, split on the horizontal diameter.

With this wheel also the thrust bearing can be removed without disconnecting the piping to it. To take care of the thrust, an automatic hydraulic piston is keyed to the shaft and held in position by a bronze sleeve extending through the stuffing-box. Penstock pressure is utilized against this bearing. Relief valves and bursting plates have been installed on the supply pipes to the several units to take care of the changes in pressure caused by fluctuation in turbine speeds or a sudden dropping of the load.

The electric equipment consists of three 3,750-kilovolt-ampere, 3-phase, 60-cycle, 6,600-volt alternators, direct connected to the wheels before mentioned. The exciter units are both 150-kilowatt, compound-wound, interpole machines, 250-volt, 720 revolutions per minute, direct connected to 300-horsepower turbines. The pipes supplying water to the exciter turbines are so arranged that they can be run from either pipe line.

The station switchboard is located on a gallery directly over the exciter sets, where is mounted on a bench board the remote-control apparatus for all switches. Over the bench board, supported by three hollow cast-iron posts, is located a board containing the indicating ammeters, wattmeters, etc. A space about 2 feet wide from the bottom of this board to the top of the back of the bench board allows the operator a full view of the main operating room. To the left of the bench board, on an ornamental pedestal that can be seen from almost any point on the gallery, are located the station frequency indicator, a synchroscope, and a voltmeter. Against the back wall on the gallery are located the panels on which are mounted the graphic recording instruments, all relays, and regulators for the entire station. A doorway in the wall back of the gallery and a little above the level of the gallery floor opens into a building that contains the low-tension switching room and busses.

The 6,600-volt cables from the alternators are carried in fiber conduits up through the first floor of this building. In this room are located all current and potential transformers. On the next floor above is the switch room proper, containing all the 6,600-volt switches, and above them the 6,600-volt busbars are carried between concrete barriers. Each bus structure controls two generators and one transformer bank, arranged for separate or multiple operation. Located in this room is the station fuse board, containing all current, potential, and operating circuit fuses or links. The leads from this board go to the operating switchboard. On the lower floor is installed a storage battery for operating the switches. Coming up through the oil room, in which are located the transformer oil tanks, oil pumps, and filters, the visitor enters the transformer building immediately in the rear of the low-tension switching rooms. The lower floor contains the transformers, each installed in a concrete compartment. A track connecting with the main line runs into the building on the level, a transfer track running at right angles with it. A 40-ton crane is used for lifting the transformers to the transfer track. Single-phase, 3,000-kilovolt-ampere, oil-water-cooled, 6,600/57,100-volt transformers are used. A reserve transformer can be cut in, in case of emergency. The floor of the transformer compartments is sloped toward the rear, and emergency drains take care of the scattered oil in case of the bursting of the transformer shell.

On the second floor of the transformer building is the high-tension switching equipment. From the oil switches the leads are carried straight up through choke coils and roof cones to the transmission line. Two electrolytic lightning arresters are located on this floor, the horn gaps of which are on the roof. Separate leads from the horn gaps through another set of roof cones extend directly down to the arresters.

The water system that supplies cooling water to the transformers is so arranged that by means of a manifold valve system there is virtually a duplicate service. Any break in either will not cause a shut-down of the transformers on account of lack of water. The oil system is provided with two means of supply to each transformer. One of them is an emergency supply for use only in case of accident; the other can be used to fill or to drain the transformers.

The power plant thus comprises three structures—the generator, the low-tension switching, and the transformer buildings. All are of reinforced-concrete construction. The generator room is 150 feet by 44 feet by 39 feet high; the traveling crane rail is 31 feet above the floor level. The low-tension switching rooms are 53 feet by 33 feet by 12 feet high. The transformer building is 88 feet by 53 feet by 49 feet high, containing two stories. The roof is supported by a steel truss, and the crane rails lie on arched buttresses.

The station lighting is furnished by tungsten lamp clusters in ornamental iron brackets, the lighting wires being run in conduit. In case of trouble the lighting system would not be interrupted, as the wiring system provides for emergency supply from the storage battery.

Hydroelectric energy for Massachusetts trolleys.—A very interesting example of tying together steam and hydroelectric plants for the operation of street railways is afforded by the Worcester (Mass.) Consolidated Street Railway System, in which a variety of old and new steam-generating stations have been supplanted and supplemented and the service revolutionized by the entrance of the 66,000-volt lines of the Connecticut River Transmission Co. into the district. The large energy consumption of such an extensive railway network makes it a desirable customer for any wholesale manufacturer of electrical energy, its demands for service extending over at least 18 hours a day. The Worcester Consolidated Street Railway serves the second largest city in Massachusetts and a tributary suburban and rural district extending from Fitchburg on the north to the Rhode Island state line on the south. It operates about 90 miles of track in the city of Worcester and 170 miles outside, its schedules demanding the daily rush-hour use of about 400 cars and meeting the traffic requirements of a territory about 40 miles long by 30 miles in width. On its lines are operated both a passenger service, varying in density from that required in the most congested city street to that suitable for cross-country or interurban service, and a rapidly growing electric express business.

For many years the principal source of power on the Worcester system was steam in various plants using the old reciprocating engines. In 1911 an important change was inaugurated by the building of a 5,000-kilowatt steam-turbine station at Millbury, 6 miles south of Worcester; the construction of a 3,000-kilowatt rotary-converter substation on Madison Street, in the heart of the city of Worcester; and the building of a 13,200-volt, 25-cycle, steel-tower line between these points. The Millbury station was planned for the ultimate addition of several units of the capacity initially installed, and a second 5,000-kilowatt turbo-generator set has been added.

Since the Millbury steam station was placed in operation, the important high-tension hydroelectric transmission system of the Connecticut River Transmission Co. has been extended into the southern part of Worcester County, and a contract has been made for the supply of energy to the Consolidated Co. at a number of points, the most important of these being at Millbury, which has thus become the operating energy headquarters of the Connecticut River Transmission Co.'s system in that region.

The yearly output of the plants connected with the Connecticut River Co.'s lines exceeded in 1912–13 that of the combined central stations of Massachusetts, with the notable exception of the Boston Edison Co., whose system covers a large part of the state. The water-power generating stations of the Connecticut Co. are located on the Connecticut River at Vernon, Vt., and on the Deerfield River in the Shelburne Falls district. The rating in 1913 of the hydroelectric station of the Connecticut Co. and its affiliated interests on the Connecticut and Deerfield Rivers was about 35,000 kilowatts.

The transmission lines form a loop from Vernon to Shelburne Falls and back through the Fitchburg, Clinton, Worcester, Millbury, and Brookfield districts, with various branch lines and an extension loop through Rhode Island to Providence, and thence back to Millbury via northeastern Connecticut. On the north side of the system the lines between Vernon and Millbury are designed for 66,000 volts and are operated at this pressure, while on the south the lines from Shelburne Falls to Millbury and thence to Providence are designed for operation at 120,000 volts. The frequency is 60 cycles. The system is already the most extensive power system in New England deriving its energy from water wheels, and its line arrangements are being carried out with the object of providing continuous service in face of every emergency which can be foreseen. Each of the main lines carries two 3-phase transmission circuits. Steel-tower construction is employed on all the high-tension trunk lines. At the Deerfield River plant, reservoir capacities aggregating 7,000,000,000 cubic feet are laid out to insure absolute uniformity in the water supply for power generation.

Energy is furnished to the Worcester Consolidated Street Railway System from the Connecticut River Transmission lines through substations at Millbury, Greendale, Fitchburg, Leominster, West Berlin, Northboro, and West Boylston, Mass., the attendance at the Greendale and Fitchburg installations being provided by the transmission company in connection with the operation of adjoining substations for its own commercial customers' services. In addition to the Madison Street substation in Worcester, the railway company operates distributing substations at Oxford, Webster, Leicester, and Sturbridge.

The Consolidated Co.'s steam generating plants have an aggregate capacity of 18,300 kilowatts, including the second 5,000-kilowatt turbine set at Millbury. The company also purchases about 330 kilowatts from the Worcester Suburban Electric Cos. at the Uxbridge generating station of the latter, so that the total auxiliary steam power available is about 18,630 kilowatts. Generators belted to water wheels and having a combined capacity of 500 kilowatts are installed in the Leominster power station of the railway company.

In general the substations on the south side of the Consolidated System are equipped with 25-cycle rotaries, while those on the north side use 60-cycle machines. At Millbury 13,200-volt lines between the Connecticut River System and the Consolidated plant provide for the supply of current at both frequencies from the water-power system. The Madison Street substation contains two 1,500-kilowatt, 25-cycle rotaries, and two 2,000-kilowatt, 60-cycle rotaries, each pair being supplied with energy through transformer banks and an independent 3-phase No. 0 copper line to Millbury, 6 miles distant.

The steam-generating plants of the Worcester Co. are as follows: Millbury, 10,000 kilowatts; Fremont Street, Worcester, 5,650 kilowatts; Unionville, 800 kilowatts; Charlton City, 400 kilowatts; Northboro, 650 kilowatts; West Berlin, 225 kilowatts; Leominster, 800 kilowatts (not including 500 kilowatts in water-wheel driven generators). The Millbury station is the only one of these which measures up to the most modern standards, and the smaller plants are useful in their reserve capacity only in relation to the power supply throughout the system. The smaller stations contain generating units of moderate capacity, frequently belt driven, and with boilers hand fired. While most of the engines are of the condensing type, the local load factors are not favorable to high steam economy, and coal supply is expensive.

The installation at Millbury includes the Consolidated Co.'s power house, a switch house for the railway company's 13,200-volt service lines on the further side of the Blackstone Canal, the Connecticut River Transmission Co.'s substation, and in connection with this, one of the most advanced outdoor types of switching and transformer installations for high-voltage service. The entire high-tension equipment, including transformers, oil switches, and lightning arresters, connected with the 66,000-volt and 120,000-volt lines of the transmission company, is located in the open air at the rear of the substation building. The transformers will eventually have three independent windings, of 120,000, 66,000, and 13,200 volts, respectively, and the station will serve as a tie-in and equalizing center between the 66,000-volt and 120,000-volt systems, and also as a step-down substation, taking energy from either or both systems and delivering it at 13,200 volts. The ultimate capacity will be about 20,000 kilovolt-amperes. There has been installed a complete switching equipment for the control and interchange of two 120,000-volt lines and two 66,000-volt lines, with the usual protective apparatus. Space is provided for four, and possibly six, 120,000-volt lines for future service. A special steel structure has been designed by the engineers of the hydroelectric organization for the support of the outdoor busses. It consists of square towers, A-frames, and latticed girders, assembled in combinations to suit the various requirements. In a brick building are installed the 3,000-kilovolt-ampere, 60- to 25-cycle, frequency-changer set, all the control panels for the Connecticut River Co.'s high-tension and low-tension apparatus, the bus structures for the 13,200-volt, 60-cycle and 25-cycle service, and low-tension lightning arresters. The station has an ultimate capacity of twelve 13,200-volt feeders, six of each frequency, and the installation consists of six 2,000-kilovolt-ampere, 66,000/13,200-volt transformers of the water-cooled type, the frequency-changer set with a 3,000-kilovolt-ampere, 3-phase transformer, and a portion of the switching apparatus.

The 120,000-volt Connecticut Power lines between Shelburne Falls and Millbury are carried on square, double-circuit steel towers, measuring 50 feet to the lowest cross-arm and 75 feet over all. The line is 60 miles long, and the towers are spaced about ten to the mile. The power conductors are of No. 00 medium-hard-drawn 7-strand copper with a ground wire of ⅜-inch double-galvanized steel strand. Suspension insulators are used, the number of disks being six in suspension and seven on strain. The line is transposed once every 20 miles, and the telephone circuit is carried on a separate pole line. In connection with the Millbury installation, a tie-line has been constructed between the Greendale substation and the former point around Lake Quinsigamond, a distance of about 11 miles, two 3-phase circuits of No. 2, 3-strand copper being used.

The steel bridges supporting the bus conductors at the Millbury switching station are in general carried 30 feet above the ground and are about 60 feet long. Disconnecting switches are installed on both sides of every oil switch. All transformers, high-tension lightning arresters, and oil switches are mounted upon concrete foundations, and the lightning arresters are installed with tanks coated with white paint to keep the electrolyte cooler when in the sun's rays than is feasible with the ordinary dark-colored tank. A concrete pier carrying three 66,000-volt oil switches is 16.5 feet long, 4 feet wide, and 3 feet high above the ground. A typical transformer pier consists of two concrete beams 20 inches wide and 22 inches above the ground in each case, carrying two 4-inch T rails 3 feet 6 inches apart, upon which rests a set of wheels permitting the more rapid movement of the transformer in case its location has to be changed quickly. Circulating water from the Blackstone River is supplied to the transformers through a system of 3-inch pipes by two triplex vertical pumps, each geared to a 5-horsepower, 110-volt, 3-phase induction motor. The water is filtered and is drawn from a well at the pump house. Wooden galleries facilitate the opening and closing of disconnecting switches from below. The disconnecting switches are composed of suspension insulators, with a hinged blade at one end and a Y-shaped spring clip at the other. Several 13,200-volt, 60-cycle feeders connect the Consolidated Co.'s switching station with the Connecticut River Co.'s substation, and in addition a feeder of this voltage leads from the frequency changer. The minimum spacing between high-tension conductors in the open-air switching station is 8 feet, and in most cases 10 feet. Choke coils are in series with the high-tension oil switch leads, and horn-gap and electrolytic arresters are liberally provided.

The frequency changer consists of a 3-phase, 24-pole, 2,300-volt, 60-cycle synchronous motor rated at 4,250 horsepower and directly connected to a 10-pole, 3,000-kilovolt-ampere, 25-cycle, 13,200-volt generator with auto-transformer, the speed of the unit being 300 revolutions per minute.

The Madison Street substation in Worcester is noteworthy through the use of 2,000-kilowatt, 60-cycle, rotary converters. These machines were among the first of their size placed in electric railway service for 60-cycle operation. Each occupies a space 10 feet 11 inches long by 9 feet 3 inches wide, the extreme length of the machine along the shaft and including the end-play being 11 feet 7.5 inches. Each has 18 poles and operates at 400 revolutions per minute, having 6-phase connections on the alternating-current side. On the direct-current side the machines each deliver 3,333 amperes at 600 volts at normal rating.

The incoming lines from Millbury terminate in a lightning-arrester house adjacent to the substation, from which underground cables are run to the second story of the latter. With 15-inch spacing between conductors, one line is carried on insulators supported on 1½-inch pipe framing, 12.5 feet above the floor, to 15,000-volt automatic oil switches. The leads from the switches thence pass through wall bushings of porcelain to the transformers supplying the two 60-cycle rotaries. Corresponding switches control the transformers for the 25-cycle rotaries, which are supplied from the other incoming line. The current transformers are placed in the incoming lines just inside the cable potheads, and an automatic oil switch is included in each line, disconnecting switches being installed between the main-line oil switches and those controlling the sets of transformers for each rotary. Individual current transformers are provided in each transformer primary circuit. The oil switches controlling each bank of transformers for the 60-cycle service are housed in concrete compartments 31 inches long and 12 inches wide per phase, the over-all width being 50 inches. Trip coils are installed at the rear of the compartments, and the ends of the latter are protected by vertical concrete slabs 56 inches high and 6 inches wide, which also serve as foundations for the pipe framing of the local disconnecting switches and current transformers. The oil switch and bus room is 120 feet long.

The transformer installation consists of three 700-kilovolt-ampere, 13,200/430-volt air-blast units for each 2,000-kilowatt rotary and two sets of three 550-kilowatt air-blast units for the smaller rotaries. All are located on top of a brick air duct in the second story of the building, immediately above the operating room. The transformer room is 126 feet long by 14 feet wide, and the air duct is 6 by 9 feet in outside dimensions, with a division wall between the two fan systems.

The Leominster, West Boylston, West Berlin, and Northboro substations are each supplied with energy from the Clinton substation of the transmission company through a 3-phase No. 1 copper line carried on a wooden-pole line owned by the Consolidated Co. Disconnecting switches are installed at convenient points in these lines for sectionalizing purposes. The poles are chestnut, 35 feet in length, set on the average 100 feet apart, and the line is supported on porcelain insulators carried on 10-foot cross-arms. The substations are of standard type, the 300-kilowatt rotary being the usual unit of equipment. The West Boylston installation is representative and consists of two 300-kilowatt rotaries, six 110-kilowatt, 13,200/370-volt oil-cooled transformers, two 45-kilowatt reactance coils, and a four-panel switchboard 5½ feet long, housed in a concrete and brick building. The incoming line is brought through choke coils and selector switches with multigraph lightning-arrester connections, the transformers being arranged in a single row with the rotaries in front. The usual direct-current feeder equipment is installed on the switchboard panels. Automatic oil switches are installed in the transformer primary leads, and practically the entire equipment is in sight on the working floor of the building. The telephone facilities include both public and private lines. At Fitchburg a 300-kilowatt rotary converter with three 110-kilovolt-ampere, oil-cooled transformers and auxiliary equipment is housed in a 19-foot by 21-foot brick extension of the Connecticut River Transmission Co.'s main 9,000-kilowatt substation in the outskirts of the city. A switchboard with two 16-inch panels, one for the alternating-current and the other for the direct-current side of the rotary, is in service, a single 500,000-circular-mil feeder being all that is needed for the Consolidated service in that district.

At Northboro a typical substation built in connection with an established steam-generating plant held for auxiliary service is in operation, with two 300-kilowatt rotaries, transformers, and auxiliary apparatus installed in a section of the engine room 19 feet by 55 feet. In this substation the arrangement of incoming line and choke coils is unusually straightforward. The wires are carried on insulators supported on pipe framing after being brought into the building through roof bushings housed in 30-inch by 36-inch inclined openings. The choke coils are mounted on horizontal axes on insulating supports carried on the framing, and the utilization of space otherwise of no value is of interest. The negative and equalizer busses are installed under the floor of the substation, and the switchboard controls the direct-current supply to feeders for cars operating in the Marlboro, Northboro, Westboro, and Shrewsbury district.

The Worcester Co.'s double-circuit, 33,000-volt line construction employs a standard pole about 35.5 feet high above the rail. The high-tension wires are spaced in 36-inch equilateral triangles, and are carried on pin-type insulators on 7-foot and 12-foot cross-arms with metal braces. The feeders are carried on 5-foot arms spaced 24 inches apart; the trolley brackets are 9 feet 6 inches long on tangents, and telephone cross-arms 3 feet long are provided immediately above. At crossings, double cross-arms are installed and the insulators are spanned by line-wire protectors.

At Millbury Junction, Mass., the 66,000-volt lines of the Connecticut River Co. cross the tracks of both the Consolidated Co. and the Boston & Albany Railroad. The arrangement of suspension insulators in the steam railroad crossing deserves mention. Each phase wire is attached to three insulators at the ends of the cross-arms of 75-foot steel towers anchored on each side of the span, the latter being about 170 feet in length. The conductors are hung 10 feet apart in a vertical plane and about 16 feet apart horizontally. Five-disk suspension insulators are used to carry the No. 00 line wires employed: The 25-foot span across the Consolidated track is effected by the use of a pair of A-frames about 50 feet high, with pin-type insulators.

The Fremont Street station, containing the original engine-driven generators of the Worcester lines, now has seven engine-driven units, all of the cross-compound condensing type, fed by twelve water-tube boilers. This station has a coal-storage yard of 20,000 tons capacity, alongside the main line of the Boston & Albany Railroad in the southern part of Worcester. An extensive coal-handling system is in service at this point, but no further description need be given of the company's steam plants, as they are gradually being retired in favor of the hydroelectric service, with the exception of the modern turbine station at Millbury. Hourly cars are operated on the principal streets of Worcester throughout the night, and the trolley is maintained alive elsewhere. All substations are shut down about midnight and started about 5.30 a. m. At the Charlton City plant one of the existing double-current generators is utilized as a rotary converter in the autumn. The night service is handled from Worcester.

Hydroelectric development at low head.—A striking instance of hydroelectric development at very low head, for street railway work, is afforded by the power station of the McKinley System on the Illinois River at Marseilles, Ill., one of the largest and earliest of its kind in hydroelectric work. The plant contains six 74-inch turbines, two 40-inch turbines, and six 62-inch turbines. The 74-inch turbines operate at 75 revolutions per minute and are rated at 450 horsepower each, at 11-foot head. These vertical units drive direct-connected alternating-current generators, two 60-cycle and four 25-cycle. The 62-inch turbines are arranged in two groups of three each, one driving a 450-kilowatt, 60-cycle generator, the other a 500-kilowatt, 25-cycle generator. The small turbines are directly connected to 90-kilowatt exciters, while a 100-kilowatt motor-driven exciter is used for relay purposes. The 25-cycle and 60-cycle systems are tied together by means of a 750-kilowatt frequency changer operating at 300 revolutions per minute.

The power plant supplies two general transmission systems, one a 25-cycle system furnishing all power requirements for the Chicago, Ottawa & Peoria Railway, the other a 60-cycle system supplying the Northern Illinois Light & Traction Co., which furnishes light and power in Marseilles and Ottawa, the La Salle Lighting Co. at La Salle, and power and light in the towns of Spring Valley, Utica, Seneca, and Morris. The hydraulic plant operates in parallel with three steam plants, one at La Salle, one at Ottawa, and one at Marseilles. It is thus possible to maintain a high load factor on the hydraulic plant while water is abundant. A feature of the 60-cycle transmission line is that a large portion of it was constructed with concrete poles. This line is built on a right of way along the bank of the Illinois-Michigan Canal.

As the head under which this plant operates is so low, special care was taken to conserve the water supply by reducing losses at every point. Trash racks with wide bars, pointed on both sides, were specially designed, and these were set against a concrete apron 1 foot below water level for the purpose of preventing the transmission of heat from the water to the cold air above, by way of the steel bars, and the resultant formation of ice on the latter. The forebay, tailrace, and river excavations were all laid out to minimize friction losses, and the speed of the wheels was so determined as to give maximum efficiency at the head used. Special generators had to be designed for the low speed of 75 revolutions per minute, but this was considered justifiable in view of the higher hydraulic efficiency obtained.

DYNAMO CAPACITY AND PURCHASED POWER.

The capacity of the dynamos installed in electric railway plants increased from 1,723,416 kilowatts in 1907 to 2,508,066 kilowatts in 1912, but it is obvious that it would have increased much more had not there been so strong a manifestation of the tendency toward purchasing power from outside sources, either central stations or power-transmission systems. Of such practice the censuses of 1902 and 1907 made no mention, because of the fact that it had not established itself, while there was also operative a contrary policy in the acquisition of such plants by the electric railways. In the intervening period the "trolleys" would appear to have had all they could do to finance themselves in meeting the growing demand for transportation facilities as such, and the managements in a great many cases have evidently reached the conclusion that it is more economical to buy the energy needed to move the cars than to produce it from plants of their own. In other words, the real problem of street railway management is better transportation and not power production. The extent to which this notable change had gone in 1912—to be more significantly evidenced in the figures of 1917—is shown by the fact that while the output of street railway plants was about six billion kilowatt hours, the current purchased amounted to very nearly three billions. Various inferences and implications depend upon such remarkable figures, the chief of which is the suggestion, already being put into effect, that in the gradual electrification of the steam railroads it will not be necessary at all for them to build expensive power plants of their own at isolated points to supply long sections of track. They can now buy current fed in every few miles, purchased at a low rate from local central stations or power-transmission lines. It is generally believed among electrical engineers that this change of method is one of the most vital and important factors in assisting the steam railroads to make the change to electricity, while avoiding altogether unnecessary investment in duplicate power plants. Elsewhere in this report are given a number of examples of the manner in which this momentous change is being worked out in practice by large railroads and street railway systems.

Electric power appears to be almost universally purchased in alternating-current form, owing, no doubt, to the fact that the substations for supplying the direct-current overhead lines of street railways have to be located solely with regard to the requirements of the railways, as well as to the fact that the present 600-volt rotary converters taking alternating current and necessary to supply the average track voltage in direct current are not available for any use other than that of railway service. There are, however, several cases where power companies have been in a position to build and equip substations mainly to carry the direct-current loads of railways, and in such cases no difficulties either in operation or in arrangement of terms for the service to the railways have been apparent.

The cost of electric power for street railway operation is a much more important matter for the larger city systems with their long hauls and liberal transfer privileges than it is for the smaller, shorter roads; and on the systems which have contracted for large blocks of purchased power the details of the contracts have necessarily been worked out with considerable care. In general, such contracts take the form of an agreement whereby the final price paid by the railway is based upon a combination of two charges. The first of these charges is made to cover the interest and depreciation of the power company's plant and is independent of the amount of power furnished. This is variously called the demand charge, the service charge, the stand-by charge, or the primary charge. It is established by the maximum amount of energy which is demanded by the railway. In other words, the charge is made because the power company holds itself in readiness to serve the railway with a certain amount of energy, and for that reason is presumably reserving a certain amount of steam and electrical equipment to carry the railway load whenever the demand comes.

This demand charge appears to be fairly well established at a figure close to $1 per month, or $12 per annum, per kilowatt of demand. This provides, theoretically, for a return of 12 per cent upon the investment of $100 per kilowatt capacity of the equipment which has to be installed to take care of the maximum peak load called for by the railway. In practice, however, the actual rate of return from the demand charge is subject to a number of important factors. The maximum demand seems never to be based upon the instantaneous peaks and but seldom upon the one-minute or five-minute peaks, the hourly basis affording a simpler method and one less liable to material errors. Naturally the establishment of the maximum peak from the average load during an hour places the burden of carrying the sudden swings which always occur in railway loads upon the power company without compensation. Approximately speaking, the necessity for providing for the instantaneous peaks eliminates the possibility of rating the generators upon their maximum momentary capacity, as much of this overload capacity of the machines is thus absorbed.

Another factor influencing the real percentage of return afforded by the demand charge is the necessity for providing spare units as a reserve against breakdown. This excess of capacity may, of course, be reduced in the cases of the very large stations, but even in plants of 80,000-kilowatt to 100,000-kilowatt capacity a margin of about 10 per cent seems to be considered to be the minimum. The proper amount of reserve capacity is, of course, actually dependent upon the size of the units in proportion to the total capacity of the plant, as well as upon the relation of the overload capacity of the prime movers to the extent by which the maximum swing is in excess of the hourly peak or whatever other arbitrary figure is used as a basis for the demand charge.

In addition to the demand charge there is another component which enters into the final price paid for purchased power. This is variously called the energy charge, the unit charge, the kilowatt-hour charge, or the consumption charge. It consists of a charge made for each unit of energy, or kilowatt hour, actually used by the railway, and for large consumptions it is usually made as a flat rate per kilowatt hour.

There is, of course, an opportunity for wide variations in the establishment of the energy charge. With large plants the over-all efficiency is approximately constant, and the labor charge for operation can vary but little, even in widely separated localities where wage scales are radically different. The cost of fuel, however, constitutes a large part of the energy charge, in some cases even 70 per cent, and as the price of coal is subject to wide variations in accordance with the locality, the energy charge is really not capable of being estimated, even roughly, for any particular case without a knowledge of all conditions surrounding it. It is, however, an interesting fact that in three of the largest power contracts yet made the energy charge amounts to about 0.4 cent per kilowatt hour consumed.

The combination of the demand charge and the energy charge takes care automatically of variations in load factor. A railway load, with very high peaks in the rush hours, will naturally have a high demand charge, and the final price paid for power is larger than that paid when the demand charge is relatively small, owing to low rush-hour peaks and a relatively high load factor. With a load factor of 30 per cent and a demand of 1 kilowatt, the monthly energy consumption will be 216 kilowatt hours, and the energy charge at 0.4 cent per kilowatt hour will amount to 86.4 cents per month, the number of kilowatt hours per month being determined by multiplying the total number of hours in a month by the demand in kilowatts and by the load factor, or 720 by 1 by 0.30. If the demand charge is $1 per kilowatt of demand per month, the total cost of power will be made up by adding the two charges together and will amount to $1.864. As the energy consumption amounts to 216 kilowatt hours, however, the final price will amount to $1.864 divided by 216, or 0.863 cent per kilowatt hour.

If, under the same conditions, the load factor is raised to 50 per cent by reducing the demand to 0.60 kilowatt and maintaining the energy consumption at the original figure of 216 kilowatt hours, the demand charge is reduced to 60 cents per month, while the energy charge remains at 86.4 cents per month. The total cost of power per month will then be $1.464, and this divided by the monthly consumption of 216 kilowatt hours gives a final price of 0.678 cent per kilowatt hour. This final price per unit of energy is more than 20 per cent below that obtained in the former case, where the load factor was only 30 per cent. Both prices are based upon charges which should be obtainable under all ordinary circumstances when power is purchased in quantities such as would be represented by demands of, say, 10,000 kilowatts or over.

The basis for power contracts outlined is so widely used that in some respects it may be considered as a standard. Actual contracts, however, modify the figures to some extent. To present an example of the general trend, the power contracts of the Chicago City Railway, the Cleveland Railway Co., and the Philadelphia Rapid Transit Co. have been compared.

The contract of the Chicago City Railway was made in 1908 and those of the Cleveland and Philadelphia systems were closed during 1912. The term of contract in all three cases is, however, specified as 10 years. The character of current supplied by the power company is thoroughly standardized. At Chicago and Philadelphia current is supplied in 3-phase, 25-cycle form. At Cleveland 3-phase, 60-cycle current is furnished, the substations of the railway company being equipped with specially designed 1,500-kilowatt rotary converters suitable for this frequency.

The voltages for the three systems are, respectively, 9,000, 13,200, and 10,000 to 11,000. In the Cleveland contract the specifications for voltage are modified by a clause to the effect that the voltage shall have "reasonably close regulation for railway purposes, provided the apparatus of the railway company is of approved design and pattern and in accordance with good practice for such operations." At Philadelphia a 3 per cent variation above or below is permitted from the normal periodicity of 25 cycles, and also from the normal voltage of 13,200.

The power factor specified at Chicago and Philadelphia is 100 per cent, approximately. At Cleveland the power factor is guaranteed by the railway company at 90 per cent or better, although apparently no specific penalty is imposed if the guaranteed figure be not maintained. But a penalty and bonus clause is added to the paragraph on this subject, which states that if the average monthly power factor varies from 90 per cent in computing the monthly settlement, the figure for demand, as measured in kilowatts, shall be arbitrarily increased or decreased as compared with the actual demand, in inverse proportion to the variation of the load factor from 90 per cent. The treatment of the power factor in the Cleveland contract is also unusual, because the method of measurement is specified. The tangent of the average monthly angle of lag is determined by multiplying by the factor 1,732 the ratio between the sum of and the difference between the readings of two single-phase watt-hour meters installed on the supply circuit. From the tangent of the angle of lag, the cosine of the angle of lag, or power factor, is determined by reference to the standard tables.

The "demand," or the figure from which the demand charge is calculated, is in all three cities established each month from hourly peaks of any three consecutive days of the month which may be selected by the power company. At Cleveland only one hour from each of the three consecutive days is selected, and this must be an even clock hour, as from 5 p. m. to 6 p. m. At Chicago and Philadelphia two hours are selected on each of the three days, one in the morning and one in the evening. The average of these hourly readings is used as the demand for the month. The arrangement works out to the advantage of the railway company, for it hardly ever happens that the heaviest three peaks in any month occur on consecutive days. The Philadelphia and Chicago contracts also have the advantage that they include in the average the figures from both the morning and the evening peaks, and, as is well known, the morning peak is by no means as severe as that in the evening. At Chicago the original contract has recently been modified in some respects, and one of the changes provides that the extra power required for heating cars when the outside air is below a temperature of 15 degrees shall be excluded in determining the maximum demand.

At Cleveland maximum and minimum figures are specified as limits for the demand, namely, 15,500 kilowatts and 10,000 kilowatts, and the minimum demand charge made by the power company is based on the latter figure, whether the power is required or not. In this contract, however, there is another clause which provides that when the demand for power in any month has increased beyond 14,300 kilowatts the minimum which shall be paid for during any succeeding month when the load may be light shall be 70 per cent of the highest demand previously made by the railway company. In other words, the final basis for the minimum demand allows for periods of light traffic a margin of 30 per cent below the heaviest previous monthly demand.

In the Philadelphia and Chicago contracts, however, the minimum guaranteed demand which must be paid for by the railway, whether the power is supplied or not, is equal to the maximum demand which has been established in any previous month. The Philadelphia contract obligates the railway to pay for 15,000 kilowatts, and if during any month the demand, as determined by the previously described method, shall exceed 15,000 kilowatts, this increased demand shall represent for that month, and for every succeeding month until it is exceeded by a subsequent still greater demand, the minimum demand for which the railway is obligated to pay. On November 15, 1913, the railway company agreed to take an additional 5,000 kilowatts, making the arbitary minimum demand equal to 20,000 kilowatts. The permissible normal increase in demand beyond 20,000 kilowatts is not definitely stated in this contract.

At Chicago the provisions for minimum or guaranteed demand are quite similar to those in the Philadelphia contract. The Chicago contract, however, states that the power company shall stand ready to supply an increase of 10 per cent over the arbitrary minimum, which is set at 30,000 kilowatts for the last nine years of the contract. This excess, however, must not be used by the railway for supplying new lines or large numbers of new cars on existing lines.

For large increases in the demand for power, such as would be required for a new substation or for new cars or new lines, all three contracts require written notice in advance from the railway companies. At Chicago and Cleveland a notice of five months is specified for increases up to 4,000 kilowatts, and 10 months' notice is required for any amount greater than this. At Philadelphia a longer time is evidently considered desirable for the installation of new machinery, since six months' notice is required for a 3,000-kilowatt increase and twelve months' notice for more than that. An interval of five months between written notices of increase in demand is required at Philadelphia and Chicago. Ten months is specified at Cleveland.

The demand charge for the original Chicago contract is based on a flat rate of $1.25 per kilowatt per month. This, however, has been reduced in a subsequent modification of the contract so that it now provides for a sliding scale as follows:

DEMAND IN KILOWATTS.	Demand charge per kilowatt.
Up to 30,000 kilowatts	$1.25
Excess over 30,000 kilowatts up to 60,000 kilowatts	1.00
Excess over 60,000 kilowatts up to 90,000 kilowatts	0.91⅔
Excess over 90,000 kilowatts up to 120,000 kilowatts	0.87½
Excess over 120,000 kilowatts	0.83⅓

At Cleveland also the demand charge is based upon a sliding scale. The demand charge for the first 500 kilowatts is $1.475 per kilowatt per month, and for the second 500 kilowatts $1.45 per kilowatt per month. For all service in excess of 1,000 kilowatts the demand charge is $1 per kilowatt per month, and this makes practically a flat rate for the demand charge. At Philadelphia the demand charge is made on a flat rate of $1 per kilowatt per month without any exceptions.

The charges for energy in the original Chicago contract are 0.415 cent per kilowatt hour during the first one and one-half years of the contract, and thereafter 0.4 cent per kilowatt hour. The Philadelphia contract also specifies an energy charge at a flat rate of 0.4 cent per kilowatt hour. In the modification of the Chicago contract a sliding scale is used which begins with a rate of 0.4 cent per kilowatt hour for the first 5,000,000 kilowatt hours consumed. For each successive block of 5,000,000 kilowatt hours, or fraction thereof, consumed in addition up to 40,000,000 kilowatt hours the price for that block, or fraction, is cut 0.005 cent, so that for any monthly consumption in excess of 40,000,000 kilowatt hours the price for the excess is 0.36 cent. Another novel feature in the modified Chicago contract is a provision for an extra charge to be made in case the price of coal of customary heating value exceeds $1.90 per ton, the normal price in Chicago.

This additional charge is obtained in dollars by dividing the total number of kilowatt hours consumed in two years by 1,000 and multiplying the result by the average excess in price over $1.90 per ton, the result being based on a consumption of 2 pounds of coal per kilowatt hour. In case the price shall drop below $1.40 per ton, the power company is to pay an equivalent rebate to the railway.

At Cleveland a sliding scale is used which specifies an energy charge of 0.95 cent for the first 50,000 kilowatt hours used in any month, 0.90 cent for the next 50,000 kilowatt hours, 0.45 cent for the next 400,000 kilowatt hours, and 0.40 cent for the next 1,800,000 kilowatt hours. For any monthly consumption in excess of 2,300,000 kilowatt hours the price for the excess amount is 0.38 cent per kilowatt hour.

At Cleveland and Philadelphia a minimum load factor of 35 per cent is definitely specified, and if this is not maintained, the energy charge will be based upon this instead of the actual energy consumption. At Cleveland the load factor is defined as the "quotient obtained by dividing the kilowatt hours consumed in any month by 720 times the maximum demand for such month," thus permitting a comparatively wide range for the minimum energy charge.

In the Philadelphia contract the 35 per cent load factor is defined as that number of kilowatt hours which will equal 35 per cent of the total number of kilowattt hours which would be consumed in any month if the energy represented by the maximum demand for that month were exerted during every hour of the month. This calculation involves the consideration of the varying number of hours in the month, which, in the Cleveland contract, is approximated by the use of the figure 720, the number of hours in a 30-day month. Otherwise, it would establish the minimum number of kilowatt hours which must be paid for at a practically constant figure, because the maximum demand, upon which the 35 per cent load factor is based, is likely to be fixed by the record load of some preceding month. At Chicago no provision is made for maintaining a minimum load factor with the exception that after the seventh year of the contract the railway is permitted to utilize sources of power other than those of the original contracting power company, but if it does so, the load factor must be maintained at 35 per cent, under penalty of paying for an equivalent number of kilowatt hours whether they are used by the railway or not.

Underground transmission lines are, in all three cases, maintained by the power company, but the substations, including the transformers, are operated and maintained by the railway. At Cleveland and Chicago the power is measured by instruments at the switchboard of the power company, but the transmission loss is guaranteed by the power company to be not more than 5 per cent. At Philadelphia, and also under the new Chicago contract, power is measured at the railway company's high-tension busbars in the substations, and in consequence the power company stands the transmission loss. The measuring instruments in this case are maintained by the power company.

Duplicate high-tension lines or their equivalent are required at Philadelphia, but at Cleveland the interruption of supply is covered by a clause requiring due diligence on the part of the power company in maintaining service and providing a rebate on the demand charge for any interruption in excess of five minutes. Length of transmission lines to new substations is covered at Cleveland only indirectly by the call for a minimum demand of 2,000 kilowatts for each new station built. At Philadelphia, if the length of transmission lines to new substations exceeds the length of existing lines the railway must pay 10 per cent per annum upon the cost of such excess length.

In all cases meters are read at noon on the last day of the month. Their accuracy is required to be within 2 per cent, and they are to be tested each month in the presence of the railway's representative at the expense of the power company. The Cleveland contract, in addition, permits testing on demand, but not more often than biweekly except at expense of the railway. Special tests may be made at any time upon written request. Corrections made in readings on account of errors in meters in excess of 2 per cent are to apply to the previous month only.

At Cleveland and Philadelphia an arbitration board composed of three members is specifically outlined for the purpose of settling questions as to the meaning of the contract. The resale of power is prohibited in every case, and the power companies are not held responsible for nondelivery of power due to causes beyond their control, although the railway companies are to have rebates equivalent to the demand charge during the period of interruption. In the Philadelphia contract a period of 90 days is allowed to the power company before the contract may be canceled, to permit it to effect a remedy of any trouble which is covered by a decision of the arbitration board.

Purchased power in New York state.—The reports furnished by the street railway companies of the state of New York to the public-service commission of the second district furnish some very interesting information in regard to the methods under which they purchase and are supplied with electric energy. Naturally, a great variety in practice is shown. Some of the examples are cited below.

The Niagara power companies have contracts which take such a form that current furnished on the basis of 100 per cent load factor is extraordinarily cheap. The price of $16 per horsepower per annum at that factor amounts to 0.245 cent per kilowatt hour. The companies, however, heavily penalize any variations from an absolutely steady load, although the price for additional power beyond the basic payment would be considered low in almost any other part of the country. In consequence, it is the custom for the railways which use Niagara power to take energy from the producer at 100 per cent load factor, or as near to that as can be obtained in practice. Most of them have steam plants floating on the line to take care of peaks. The contracts of the Niagara power companies generally include the term "firm power." This term applies to the quantity of power which the purchaser agrees to buy, and the purchaser pays for it whether it is used or not. In consequence, this power is used at 100 per cent load factor. Additional firm power, or a normal increase in the demand, is also furnished at 100 per cent load factor. The price of additional firm power does not necessarily agree with that charged for original firm power, for the reason that, opposing the tendency toward a decreased price on account of increased quantity, there may be necessity for considerable additional expense on the part of the power company in providing for the increased demand, such, for instance, as new cables, poles, or connections. Additional kilowatt hours in these contracts are sold on a straight kilowatt-hour rate basis, and the matter of load factor is not taken into consideration. While this charge is often less than 1 cent per kilowatt hour, it appears extremely high when compared with the 0.245 cent per kilowatt hour often used as a basic price for firm power, and in localities fortunate enough to be served by the Niagara companies there is a strong endeavor to avoid such payments.

Following are summaries of certain power contracts in New York state which were reported to be in existence during the year ending June 30, 1912:

Adirondack Lakes Traction Co. had a contract with Fonda, Johnstown & Gloversville Railroad for power, not measured, at $15 a day.

Albany Southern Railroad purchased 4,593,211 kilowatt hours from its own electrical department at 0.67 cent per kilowatt hour.

Babylon Railroad has a contract, dated September 19, 1910, with the Babylon Electric Light Co. to furnish electric energy from July 15, 1910, to the fifteenth of each succeeding month. The consideration is $450 for 15,000 kilowatt hours, 2.5 cents per kilowatt hour for each kilowatt hour in excess of 15,000 and less than 25,000, and 2 cents per kilowatt hour for each kilowatt hour in excess of 25,000, unless the total consumption shall be less than 12,857 kilowatt hours, when the rate is 3½ cents for each kilowatt hour during any one month. During the year ended June 30, 1912, 163,660 kilowatt hours were supplied at 2.9 cents per kilowatt hour. Power is being furnished at $450 per month during the summer season and at $375 per month during the winter season.

Buffalo & Depew Railway has a contract with the Niagara, Lockport & Ontario Power Co., dated January 3, 1910. It expires March 1, 1930, and the consideration is $16 per horsepower per annum and 0.55 cent per kilowatt hour. During the year ended June 30, 1912, 380,000 kilowatt hours were supplied at 0.549 cent per kilowatt hour. In addition to the kilowatt hours, power was purchased as follows: 1,366 horsepower at $16 per horsepower year, for $21,856, plus $261 for excess peaks.

Buffalo & Lake Erie Traction Co. purchased during the year ended June 30, 1912, 8,954,987 kilowatt hours from the Niagara, Lockport & Ontario Power Co., at 0.702 cent per kilowatt hour, and also 1,465,740 kilowatt hours from the International Railway at 1.131 cents per kilowatt hour.

Buffalo & Williamsville Electric Railway had a contract with the Genesee Light & Power Co., Batavia, N. Y., under which the first power was delivered August 2, 1909. The contract expired five years from that date. The consideration was 3.75 cents per car-mile with a minimum monthly rental of $250 based upon a minimum demand of not exceeding 100 kilowatts. The company also has a contract with the Niagara, Lockport & Ontario Power Co., dated March 18, 1910, and expiring 10 years from May 1, 1910. The consideration for each electric horsepower delivered is $16 per year as the service charge and, in addition, 0.55 cent for each kilowatt hour used when the firm power is less than 300 horsepower, 0.5 cent for each kilowatt hour used when the firm power is 300 horsepower or more but less than 500 horsepower, 0.47 cent for each kilowatt hour used when the firm power is 500 horsepower or more but less than 750 horsepower, and 0.44 cent for each kilowatt hour used when the firm power is more than 1,000 horsepower. The service charge is based on the average of the highest daily one-minute peaks.

Catskill Traction Co. has no formal agreement, but power is bought of the Schoharie Light & Power Co. The total number of kilowatt hours supplied during the year was 261,400, the total gross charge being $4,621.28, at an average net price per kilowatt hour of 1.75 cents.

Eastern New York Railroad Co. purchased during the year ended June 30, 1912, 202,675 kilowatt hours from the Adirondack Electric Power Corporation at a price of 1.5 cents per kilowatt hour measured on the alternating-current side.

Elmira, Corning & Waverly Railway purchased from the Elmira Water, Light & Railroad Co. 1,576,514 kilowatt hours at a price of 1.5 cents per kilowatt hour.

Fishkill Electric Railway Co. purchased 358,904 kilowatt hours from the Southern Dutchess Gas & Electric Co. at a price of 3.5 cents per kilowatt hour.

Hornell Traction Co. paid the Hornell Electric Co. in the year ended June 30, 1912, for power for city cars at a rate of $2.35 per car per day, and for the Canisteo cars at the rate of $3.65 per car per day.

Hudson River & Eastern Traction Co. was supplied with 302,880 kilowatt hours by the Northern Westchester Lighting Co., the rate being 2.5 cents per kilowatt hour.

Ithaca Street Railway Co. pays the Remington Salt Co. for such quantities of electricity as it may require at the rate of 1 cent per kilowatt hour for alternating current at the switchboard of the generating station. In addition to this, the railway company pays one-half of the labor cost in the engine room of the power station, amounting to $167 per month.

Lima-Honeoye Light & Railroad Co. purchased from the Livingston Niagara Power Co. 172,172 kilowatt hours at 3.14 cents per kilowatt hour.

New York & Stamford Railway Co. paid the New York, New Haven & Hartford Railroad Co. for 155,740 kilowatt hours at a rate of 1.25 cents per kilowatt hour.

New York Central & Hudson River Railroad Co. paid the Rochester, Syracuse & Eastern Railroad Co. for power at a rate of 2 cents per kilowatt hour, $1,119.50 for 55,975 kilowatt hours.

New York State Railways bought of the Rochester Railway & Light Co. 45,442,298 kilowatt hours at 1.0942 cents per kilowatt hour, amounting to $497,222.50.

Northport Traction Co. has no contracts or agreements, but purchased of the Long Island Railroad 63,546 kilowatt hours at a rate of 5.52 cents per kilowatt hour, amounting to $3,509.61.

Orange County Traction Co. purchased from the Central Hudson Gas & Electric Co. 254,370 kilowatt hours, costing $4,425.12, at a rate of 1.78 cents per kilowatt hour. The company also purchased from the Walkill Power Co. 674,158 kilowatt hours, costing $8,425.85, at a rate of 1.25 cents per kilowatt hour.

Otsego & Herkimer Railroad Co. purchased of the Hartwick Power Co. 3,909,979 kilowatt hours at a rate of 1.67 cents per kilowatt hour, amounting to $65,435.05.

Plattsburgh Traction Co. purchased power from the Plattsburgh Gas & Electric Co. at 1.5 cents per car-mile operated, the kilowatt hours not being measured. The cost for the year was $2,265.04.

Several other similar instances in the state could be cited.

Purchased power for operation of Pennsylvania Railroad suburban lines.—The Pennsylvania Railroad has announced that the contract for the electrical energy for the electrification of its lines between Broad Street Station and Paoli, and also between Broad Street Station and Chestnut Hill, has been made with the Philadelphia Electric Co. The contract is for five years. At the beginning the Pennsylvania Railroad will use about 5,000 horsepower, a minimum of 3,750 kilowatts, with a load factor of 25 per cent, being specified. The energy is to be furnished for the main line to Paoli and any addition or extension thereto, the railroad company reserving the right to call on the Philadelphia Electric Co. for any additional power that may be necessary for its general system from time to time. With the completion of the present work as planned, the Pennsylvania Railroad will have 32 miles of electrified lines in the Philadelphia suburban district. The cost of the energy to the railroad company for the Paoli line for the first year will be about $150,000. The Philadelphia Electric Co. now feeds a load of 35,000 horsepower daily for the Philadelphia Rapid Transit Co.

Power rate for Puget Sound Railway.—The plans for the electrification of the Chicago, Milwaukee & Puget Sound Railway, from Harlowton, Mont., to Avery, Idaho, a distance of 440 miles, include the supply of wholesale power from the Great Falls Power Co., Great Falls, Mont., with plants at Rainbow Falls and Black Eagle Falls, on the Missouri River. The railway company agrees to electrify its line between Harlowton and Deer Lodge, Mont., a distance of 238 miles, before January 1, 1918, and also agrees to buy from the power company electric energy at the rate of 10,000 kilowatts, maximum demand, for the full period of the 99-year agreement, but two years' notice will be given the power company that delivery must commence. The railway company has several options for more power up to a total of 25,000 kilowatts, maximum demand, the agreement as to this additional demand being as follows: Not less than 4,000 kilowatts nor more than 8,000 kilowatts, if called for prior to January 1, 1923; not less than 3,500 kilowatts nor more than 7,000 kilowatts, if called for at any time between January 1, 1918, and January 1, 1928, and if at least 6,300 kilowatts additional has been called for prior to January 1, 1923. Additional energy, when once called for as above, will be supplied for the entire remaining term of the contract. Delivery of energy will be made to not more than five stations between Deer Lodge and Harlowton, at 50,000 volts or 100,000 volts, 3-phase, 60-cycle, alternating current. The railway substations are to contain sufficient synchronous machinery to secure a power factor, leading or lagging, of at least 80 per cent. Twelve months' notice will be given the power company of the location of the delivery points. The power company will also have the right to install regulators in the substations for the operation of synchronous machinery in such manner as to receive any power factor between 80 per cent leading and 80 per cent lagging. The rate for energy will be 5.36 mills per kilowatt hour, subject to a minimum bill, after the first year of service, equivalent to 60 per cent of all the energy contracted for. The power company is also required to pay the Federal Government a tax of 5 mills per 1,000 kilowatt hours for all energy delivered over transmission lines crossing the public domain. This region is mountainous, embracing some very heavy grades, and it is estimated that electrical operation will result in large financial saving.

LINE CONSTRUCTION.

Line-construction features.—The subject of line construction has received increasing attention from street railway companies in recent years, and its treatment at the hands of the committee on power distribution of the American Electric Railway Association takes the shape of voluminous yearly reports which cover all branches of the work. In no department has the trend toward standardization been more strikingly manifested. A great many conditions are involved in the maintenance of overhead-line trolley service with relation to continuity of service; supply from power-transmission lines; joint use of poles; overhead crossings on steam railroad tracks or with other wire systems; nature of poles; use of concrete, lattice, or tubular metal poles; trolley guards; and numerous other features of the service. These could only be dealt with adequately by quoting in full the specifications of the American Electric Railway Association as to such items, constituting a formidable volume of specific data. It will be sufficient here to note some instances of modern practice under which the industry is operated.

Probably the most important feature of all is the safeguarding of lines which connect with outside sources of current supply, for within city limits the familiar methods of central poles, side brackets, and cross suspension seem to have become thoroughly standardized and accepted. One hears very little about them, and there is a notable absence of discussion of them in the technical press. There is a refinement of method in this field, rather than any radical change.

Transmission lines in Georgia.—An excellent example of work in the field of power-transmission service is furnished by the lines for the service of the Georgia Railway & Power Co. of Atlanta, Ga., from the famous Tallulah Falls. The energy from the Tallulah Falls station is transmitted over a steel-tower line from

Tallulah Falls to Atlanta, a distance of 90 miles; from Atlanta to Lindale, a distance of 80 miles; and also from Atlanta to Newnan, a distance of 50 miles. The main line from Atlanta to Tallulah Falls is constructed with six No. 0000 copper conductors and two $\frac{7}{16}$-inch, 7-strand, galvanized-iron ground wires, the latter being mounted on the ends of cross arms at the tops of the towers above the cross arms carrying the main lines. The transmission lines from Atlanta to Lindale and from Atlanta to Newnan are constructed with No. 00 copper, the same general type of construction as on the main line prevailing. The insulators are all of the suspension type, four-disk, two-part insulators being used on the main line from Tallulah Falls to Atlanta, and insulators with five 10-inch disks on the other circuits. A telephone circuit of No. 4 special 30 per cent copper-clad wire is also strung on the towers and insulated by 15,000-volt insulators. The telephone line is continuous from the power house to all of the substations, and at each interval of 4 miles a small telephone booth supplied with a high-voltage switch, which completely isolates the telephone apparatus when not in use, is provided. At the various terminals and at the Boulevard substation in Atlanta there are located special high-frequency or tuned telephone calling circuits for signaling the specific points desired without interfering with the magneto calling systems. The telephone line is protected by the use of horn gaps to ground on the high-voltage side and by a new multicylinder type of oil-filled arrester.

A novel method of transposition is accomplished by having the telephone circuits placed on insulators with pins of different heights. The wires enter the tower in a nearly horizontal plane—one on a high pin and the other on a low pin; that on the high pin crosses diagonally to another high pin on the far side of the tower, and that on the low pin crosses to a low pin, the wires clearing each other by about 5 inches. This method of making transpositions does away with the customary deadening of the line and connecting of opposite wires with a jumper.

The steel transmission towers used on the line are spaced about 17 to each 2 miles. Three standard types, 66 feet, 70 feet, and 80 feet in height, are used, the first for the No. 0000 copper circuits of the main line, the second for the No. 00 circuits of the lines running to Newnan and to Lindale, and the third to carry the high-tension and low-tension circuits around the outer zone of the city of Atlanta. The bases of the towers, which are square, have side dimensions of 16 feet, 18.5 feet, and 20 feet, respectively.

The 110,000-volt wires are spaced on 9-foot centers suspended vertically, one 3-wire circuit on each side of the structure. The towers on the main line weigh 5,554 pounds, those on the branch lines weigh 4,721 pounds, and the special towers used around the city of Atlanta weigh approximately 8,000 pounds. The cross arms are of standard channel-iron section and the tower legs are of angle-iron section. Special U-bolts secure the suspension insulators to the cross arms. The footings are made by extending the tower-corner angles into the ground to a depth of about 7 feet, and footing angles are bolted to the bottom ends. In addition to the standard towers, special angle towers are used for line angles above 10°. The latter towers are of the same design as the standard tower, but of heavier section, and have eccentric cross arms to take care of clearances for angle location. These strain towers on the main lines weigh 6,880 pounds and those on the branch lines weigh 6,680 pounds. In a number of places towers 105 feet high are used.

The towers, of which there are, all told, 1,754, were tested for vertical, horizontal, and torsional loads before shipment. The towers for the main lines were designed for a longitudinal pull of 4,300 pounds at right angles to the end of any one cross arm, a vertical load of 1,500 pounds at the end of any or all cross arms, a load of 1,500 pounds pulling at the top of the tower in any direction, and a load of 10,000 pounds pulling at right angles to the line or parallel to the cross arms; and at the same time a pull of 8,000 pounds vertically to the line or at right angles to the cross arms—that is, 4,000 pounds at each end of one single cross arm or at each of any two ends of any two cross arms. The towers for the branch lines were designed for a longitudinal pull of 3,000 pounds, a vertical load of 1,200 pounds, a load of 1,200 pounds pulling in any direction at the top of the tower, a load of 8,000 pounds pulling at right angles to the line, and at the same time a pull of 5,000 pounds longitudinally to the line or at right angles to the cross arms. The cross arms are proportioned for a combined load of a longitudinal pull of 3,000 pounds, a vertical load of 1,200 pounds, and a horizontal thrust of 1,000 pounds at the ends. The material used in the construction is all thoroughly galvanized, and sherardized bolts were employed in assembling the various parts.

Transmission system in Missouri.—One of the larger interurban systems of 1912–13 is that of the Kansas City, Clay County & St. Joseph Railway, which is a good example of the modern method of connecting cities electrically by trolley in face of steam competition. There are six steam roads operating for freight and passenger business between the terminals named, and a seventh competitor would seem wholly superfluous, but various advantages pertain to the electric method for high-speed, short-route purposes. Current is received from outside sources at 33,000 volts, 25 cycles, being converted to 1,200-volt direct current at five substations along the two divisions of the line. One pole line is used to carry the trolley wire and 3-phase transmission line, one telephone circuit, and the feeder cable, space being allowed on the cross arms for signal wires. The plan is such that the road may ultimately be operated at 1,500 volts direct current, with 1,200 volts direct current for initial operation. The design is also initially for single track, permanently located on the right of way as one of the tracks of a double-track road.

In general, five-point catenary bracket construction is used, span construction being employed only on long overhead viaducts and bridges and for short distances in the cities. Bracket construction is also used on the 15 sidings on the St. Joseph division and the 8 sidings on the Excelsior Springs division, a line of poles being set on the outside of the siding and opposite the main line of poles. With this design, in case the line is double-tracked the siding poles may be used as main-line poles without change.

The pole spacing is 150 feet on tangent line and less on curves, the distance depending upon the degree of curvature. The accompanying table gives approximately the spacing used on curves, also span and pull-off spacing.

TABLE SHOWING POLE SPACING, ETC., ON DIFFERENT DEGREES OF CURVES.

Brackets.	Degree of curve.	Pole spacing.	HANGERS.		Sag.
			Straight line.	Pull-off.	
Feet.		*Feet.*	*Number.*	*Number.*	*Inches.*
9	Tangent to 1°	150	5	....	16
12	1° to 2¼°	150	4	1	16
12	2¼° to 3½°	135	4	1	13
12	3½° to 4°	120	4	1	10
12	4° to 5½°	105	4	1	8
12	5½° to 7½°	90	2	1	6
12	7½° to 10°	75	2	1	4
12	10° to 17°	60	....	2	2½
12	17° to 80-foot radius	45	....	3	....

All sags are calculated to a temperature of 60° F. The sags above given are from the center of the messenger to the center of the trolley, equal to 22 inches at the bracket arm.

All poles are Michigan white cedar, those carrying transmission lines being 40 feet in length and those without transmission lines 35 feet in length. All poles have a diameter of 8 inches at the top to comply with the Northwestern Cedar Men's Association standard specifications for electric poles. As a rule, the poles were framed before being set, and the pins and insulators placed on the cross arms. In special instances, where the wires pass over foreign transmission and telephone lines, poles having a length as great as 60 feet are used. The following table gives the pole settings for different lengths of poles:

35-foot poles in the ground 6 feet deep.
40-foot poles in the ground 6 feet deep.
45-foot poles in the ground 6 feet 6 inches deep.
50-foot poles in the ground 7 feet deep.
55-foot poles in the ground 7 feet 6 inches deep.
60-foot poles in the ground 8 feet deep.

On curves all poles are keyed with stone or timber, and in soft ground are set in concrete at points of special strain. Poles on bracket construction are set with their faces a distance of 7 feet 6 inches from the center line of the track, and on straight line they are set with a rake of 8 feet from the track. On span construction through towns, and at other places where such procedure was necessary, the main pole or poles are set with a rake of 2 feet and the 35-foot poles opposite with a rake of 4 feet. Where guying was necessary, ⅜-inch, 7-strand, galvanized-steel wire having a tensile strength of 5,000 pounds was used, the pole being protected by galvanized-iron bands where the guy wire passes around it. Wood-strain insulators are cut into all guy wires at a distance of 8 feet from the pole, and the guys are anchored to ⅝-inch by 6-foot anchor rods, passed through 6-inch by 8-inch by 8-foot ties, buried 5 feet deep. All guying was done before any strain was brought on the poles by the erection of any high-tension trolley or feeder wires.

The cross arms are of Washington fir, with dimensions as follows: For the 33,000-volt, high-tension line, 5 inches by 6 inches by 10 feet, four pin; feeder arm, 3½ inches by 4½ inches by 4 feet, three pin; telephone cross arm, 3½ inches by 4½ inches by 8 feet, eight pin. Spaces have been allowed on the telephone and feeder cross arms for the installation of signal wires. The high-tension cross arm is placed at the top of the pole and is braced with 1½-inch by 1½-inch by 3/16-inch angle brace having a spread of 5 feet. The feeder arm is placed second from the top, immediately above the bracket arm, and the telephone arm just below the bracket arm. On curves of 2 degrees and greater, iron pins having a ¾-inch by 7-inch shank and a 4¾-inch curved base, to fit 5-inch by 6-inch arms and extending 7½ inches above the high-tension cross arms, are used. For high-tension lines along tangent track locust pins 13 inches over all and having a 1¾-inch by 6-inch shank, to fit 33,000-volt insulators, are installed. For the direct-current 1,200-volt feeders the company uses 1½-inch by 4½-inch shank, locust pins, 9 inches over all, and for the telephone line 1½-inch by 4½-inch shank, locust pins, 9 inches over all. For telephone transposition, 1½-inch by 4½-inch shank, locust pins, 10 inches over all, are used.

All insulators on the St. Joseph division are brown porcelain, having a wet flash-over test of 68,000 volts and a dry flash-over test of 90,000 volts. The high-tension line on the Excelsior Springs division is carried on porcelain insulators having a wet flash-over test of 70,000 volts and a dry flash-over test of 133,000 volts. All 1,200-volt feeder insulators are designed for a working voltage of 6,600.

The 9-foot bracket arms are 2½-inch by 2¼-inch by ¼-inch T-sections, with ⅝-inch tension rods. All brackets are black japanned. For tangent steadies on inside curves the bracket arms are 12-foot long, 2¼-inch by 2¼-inch by 5/16-inch T-sections with ⅝-inch tension rods. These also are black japanned. The messenger insulators are designed for a test voltage of 20,000 volts.

On span-wire construction, ⅜-inch, 7-strand galvanized-steel cable having a tensile strength of 5,000 pounds is used. This is attached to the poles with

$\frac{5}{8}$-inch by 14-inch galvanized eyebolts. These eyebolts are placed at such a height as to allow for a dip in the span wire of 1 foot in 10 feet, with the eyebolt run out its full length. Wood strains are cut into the span wire 8 feet from the trolley on either side and into the pull-offs and bridle guides. The catenary cable is supported at the center of the span by Westinghouse cross-stand messenger hangers.

The catenary construction is of the single-messenger type, the sag at the center being approximately 16 inches. The messenger is $\frac{7}{16}$-inch steel strand, having a tensile strength of 9,000 pounds and an elastic limit of 5,300 pounds. Five-point suspension, with flexible catenary hangers and curve pull-offs, is used.

The trolley wire used is No. 0000 B. & S. gauge, hard-drawn standard grooved copper having a tensile strength of 46,500 pounds per square inch. The height of the trolley wire is 19 feet above the heads of the rails.

The feeder wire is 500,000-circular-mil bare-stranded copper cable, composed of 37 strands, each having a diameter of 116.2 B. & S. gauge, concentric type. This cable is strung the entire length of both the Excelsior Springs and St. Joseph divisions. It is tied to the insulators with No. 6 B. & S. soft-drawn copper wire and is rope-spliced and soldered. This feeder was erected before the bracket arms were put in position, and is placed on the track side of the pole.

The trolley and messenger is sectioned at four points, one being on each division to insulate the 1,200-volt railway current from the 600-volt current of the Union Depot Bridge & Terminal Railway, one at the substation on the Excelsior Springs division, and one at substation B on the St. Joseph division. Twelve-hundred-volt section insulators are used. The feeder is tapped into the trolley approximately three times per mile. The taps are No. 0 B. & S. copper wire, soldered to the feeder and run through two feed-tap porcelain insulators and fastened to the feed-tap trolley feeder.

Twelve-hundred-volt arresters are used for the protection from lightning of the feeder and trolley wires. These arresters are located about five to the mile and are so spaced as to bring an arrester on each pole where a feed tap is located. These arresters are placed about 17 feet above the top of the rail and each is connected to the feeder wire by means of a No. 6 B. & S. copper wire which is soldered to the No. 0 B. & S. copper wire and is stapled to the pole with galvanized fence staples. The end is soldered to the brass cap of a $\frac{3}{4}$-inch by 7-foot galvanized-iron pipe having a driving point placed at one end and the brass cap at the other end. This pipe is driven directly underneath the lightning arrester to a depth of 6 feet, leaving 1 foot above the ground.

The high-tension, 33,000-volt, 3-phase, 25-cycle transmission line is carried from the Metropolitan power house in Kansas City to the junction transformer station by three 300,000-circular-mil bare-stranded feeder cables. From the transformer to substation A on the St. Joseph division, a distance of about 12 miles, three No. 2 B. & S. medium hard-drawn bare copper wires are used. These are supported on insulators and pins as stated above and tied in with No. 6 soft-drawn B. & S. copper tie wire. From substation A to substation B, a distance of about 26 miles, and also from the transformer station to substation C on the Excelsior Springs division, three No. 4 B. & S. medium hard-drawn bare copper wires are strung.

For the protection of the high-tension lines a No. 6 B. W. G. galvanized-steel wire is strung over the tops of all high-tension poles. It is placed at a height of 22 inches above the top of the pole and 3 feet 6 inches above the top of the high-tension cross arm, and is fastened to a porcelain knob, which in turn is bolted to a 2-inch by 2-inch by $\frac{3}{16}$-inch by 3-foot 6-inch angle iron. This ground wire is grounded approximately five times to the mile by means of No. 8 B. W. G. galvanized-steel wire, which extends down the track side of the pole and is fastened at intervals of 5 feet with galvanized-iron fence staples. This wire is attached to the ground wire by wrapping and soldering and is grounded at the base of the pole to a $\frac{3}{4}$-inch by 7-foot galvanized pipe, having a driving point and brass cap, and driven into the ground at the base of the hole.

The telephone circuit consists of two No. 10 B. & S. copper wires. This line is transposed every 1,000 feet, the transposition being made on one transposition insulator. Telephone jack boxes are placed every mile and at all sidings for the entire length of each division.

Pacific Electric Railway catenary construction.—During 1911 to 1913 the Pacific Electric Railway of Los Angeles, Cal., installed over 50 miles of catenary construction on about 40 miles of route, with the intention of making this method or type its standard on interurban lines. The heavy service conducted by the company makes a straight-running working conductor, such as is furnished by a catenary overhead construction, extremely desirable, as will be seen from the statement that the trains of three or more cars, each car weighing over 80,000 pounds, are often run at speeds on the interurban stretches of 60 miles per hour or more, and that long freight trains are operated by 60-ton locomotives. The amperage which is collected from the wire at high speeds is consequently very large, and it would probably have been impossible to collect the requisite amount of current from the overhead system if the company had not for a long time been using a trolley with a pneumatic base, by means of which a pressure of about 30 pounds is put upon the wire at the trolley wheel. The problem of overhead collection has thus been greatly reduced.

In the standard pole and bracket construction used in the latest catenary work of the company, one system includes a pole designed to carry also a single transmission line; the other, a double transmission line. In the former case the three wires are carried in the same horizontal plane, an arrangement which differs from the usual triangular plan, but is considered by the company better where the length of transmission is not too great, so that there will not be any serious unbalancing effect from induction. The three transmission wires are carried on a single cross arm so that they are easily accessible to the linemen. In the second arrangement the three transmission wires are in a vertical plane, and as the cross arms are 8 feet in length this arrangement also permits easy access to the wires by the linemen. In tangent catenary construction the poles are spaced 150 feet apart, this distance being shortened on curves to 60 feet, even for a 1-degree curve. The transition from 150 feet to 60 feet is made gradually.

A variety of types of hangers and insulators has been used in the catenary construction already installed, including the Southern Pacific type of hanger with round loop at the top and the commercial type of strap hanger with an extended flap loop. The hangers are spaced 15 feet apart. The company has found it necessary to use tie spans to the trolley wire at occasional intervals on tangents to hold it in position. At present these spans are being used about every 300 feet. Otherwise the wire would cant, especially under heavy side-wind pressure and when pressed up by the trolley pole. The company is constructing all of its catenary line for 1,200 volts, because it has planned to change gradually to this high voltage on the interurban sections. It is also planning gradually to change from the ordinary overhead construction to the catenary construction.

In all of its overhead construction the company treats the bases of its poles to prevent decay, the treatment being applied to the portion of the pole under the ground and for a distance of 1 foot or 2 feet above the ground. This corresponds to about one-seventh of the length of the pole. The process consists of charring the butts or portions treated over a fire made of shavings, and, while the charred wood is still hot, pouring crude oil over it. In this way charcoal forms readily, and good penetration for the preservative material is secured. This process is applied in the pole yards and costs about 50 cents per pole for material and labor. The oil used is the ordinary crude oil, which costs in Los Angeles about 75 cents a barrel. After the pole is erected it is painted.

Statistics of wooden poles.—Statistics of the number of wooden poles purchased in the United States in 1911 by steam and electric railroads, electric light and power companies, and telephone and telegraph companies are presented in a bulletin issued by the Bureau of the Census. The figures include the pole purchases of practically all of the telephone and telegraph, electric railroad, electric light and power, and steam railroad companies, and accordingly reflect very closely the actual drain upon the pole timber forests of this country. The bulletin was prepared under the supervision of W. M. Steuart, chief statistician for manufactures.

In 1911 the total purchases of poles in the United States amounted to 3,418,020 sticks of timber; of these, 2,402,724, or 70.3 per cent, were purchased by the telephone and telegraph companies; 787,649, or 23 per cent, by the electric railroad and electric light and power companies; and 227,647, or 6.7 per cent, by the steam railroads. The total number of poles purchased represents a decrease of 452,674 as compared with 1910, and of 320,720, as compared with 1909, but it exceeds the totals for 1908 and 1907 by 168,886 and 134,752, respectively. The decrease in the purchases of 1911, as compared with 1910, was confined to telephone and telegraph companies and steam railroads, while substantial increases in purchases were reported by the electric railroad and electric light and power companies.

Five kinds of wood—cedar, chestnut, oak, pine, and cypress—supplied over 90 per cent of the pole requirements of the United States during each of the five years 1907–1911. Cedar, which has long been the preferred wood for pole purposes, supplied 61.4 per cent of the total number reported in 1911. Purchases of chestnut increased substantially from 1908 to 1911, amounting in the latter year to 177,440 more than in 1908. The number of oak poles used increased rapidly from 1907 to 1910, but decreased greatly in 1911, in which year the number reported was more than 65,000 below the figure for 1910. The use of pine has increased but little since 1907. The demand upon cypress has fallen off slowly year by year, the number of cypress poles purchased in 1911 being only about three-fourths as great as the number purchased in 1907. This falling off is due to the high price of cypress lumber and to the fact that this timber is found generally in sizes too large for poles.

The preferred species of wooden poles have the general physical qualifications of durability in the soil, strength, lightness, straightness, a surface which will take climbing irons readily, and comparatively slight taper. The various species of cedar combine these qualities in high degree. Cedar poles are cut principally from the white cedar of the Lake states, the red cedar of the Northwest, and the southern white cedar of North Carolina, Virginia, and New Jersey. Chestnut is cut principally in the Atlantic Coast states from Georgia to New Hampshire. Oak, a very widely distributed species, is cut for poles chiefly in the hardwood states of the Ohio and Mississippi Valleys. Most of the pine reported is that commonly known as southern yellow pine and includes several species—long-leaf pine, short-leaf pine, loblolly pine, and some others. Of these, the most durable is the long-leaf pine, while the loblolly pine gives very brief service unless it is treated with a preservative. In the West another species—western yellow pine—is reported, which also requires preservative treatment.

The woods used for poles in the United States are chiefly those which are naturally very durable in contact with the soil. The life of timber under this condition varies considerably according to the species, to differences in the wood of the same species, to the character of the soil, and to climatic conditions. Cedar, chestnut, cypress, juniper, and redwood usually last from 10 to 15 years, while white oak has an average life of somewhat less than 10 years.

The resistance of the poles to decay can be considerably increased by the use of preservatives. Wood preservation is now on a firm footing in the United States, but the advantages which this practice affords are by no means fully utilized by the pole consumers. Preservatives not only add from 3 to 15 or more years to the service of the woods now commonly used for poles, but also make it possible to use cheaper woods which in their natural condition lack durability in the soil, although possessing all the other qualities necessary in pole timber. The durability of woods which ordinarily last but a few years can thus be increased to more than double the normal life of cedar.

The principal preservatives used for treating poles are those classified as refined coal-tar oils. Under this heading are included creosote oil and various proprietary preservatives. Creosote oil was used in treating 159,321 poles, of which 50,021 were cedar and 83,035 yellow pine. The cost of treating poles varies according to the wood treated, the kind of preservative and quantity used, and the process employed, but it is only in rare instances that the adoption of a pole-treating policy is not economical. During 1911, 656,504 poles were reported as having had some kind of preservative treatment. This number exceeded the total for 1907 by 260,305, that for 1908 by 312,116, and that for 1909 by 79,873, but was less by 168,169 than the number reported as having been treated in 1910.

The following statement shows, by varieties of wood, the number of poles purchased in each year from 1907 to 1911, inclusive:

KIND OF WOOD.	1911	1910	1909	1908	1907
Total	3,418,020	3,870,694	3.738,740	3,249,154	3,283,268
Cedar	2,100,144	2,431,567	2,439,825	2,200,139	2,109,477
Chestnut	693,489	677,517	608,066	516,049	630,282
Oak	199,590	265,290	236,842	160,702	76,450
Pine	161,690	184,677	179,586	116,749	155,960
Cypress	72,995	75,459	77,677	90,579	100,368
Juniper	27,847	20,042	43,581	42,367	38,925
Redwood	26,887	30,421	23,145	13,061	31,469
Douglas fir	24,833	56,732	24,877	19,542	15,919
Tamarack	23,543	30,964	29,889	24,123	13,884
Osage orange	21,101	23,221	21,491	18,109	5,962
Spruce	10,166	22,929	11,423	8,088	10,646
Locust	8,477	9,030	10,463	10,224	4,672
All other	47,258	42,845	31,875	29,422	89,254

Employment of concrete poles.—The last few years have seen a marked increase in the use of concrete poles and in the attention given to them by street railway managers as a substitute for both wooden and metal poles. An example is furnished by the New York State Railways, which, during 1910, 1911, and 1912, utilized these poles on a large scale and established a plant for their production with a capacity of 10 to 15 poles per day. These poles are cast in timber molds of the usual type. The specification as to material is as follows:

Before casting poles, oil form inside with a mixture of one part black oil and one part gasoline. This oiling to be done immediately before casting pole.

The concrete mixture to be formed from one part cement, two parts sand, and two parts stone, measurement to be made by volume.

All stone used to be clean and free from loam or dirt. Thoroughly wet the stone in the pile before mixing.

Sand to be free from loam or dirt. Place the proper amount of sand on the mixing board and spread out to a thickness of 4 inches. On this sand place the cement and turn both three times, after which apply the water and turn so that the mass is entirely wet. Spread out this mortar again in a 4-inch layer and dump the stone in another layer on top. Turn the mortar and stone until mortar and stone are thoroughly intermixed. The concrete mixture must not be left on the board long enough to require retempering, but should be placed in the forms at once.

In placing the reinforcing rods great care must be used properly to locate the same and maintain in the proper position.

The time of removing of side forms and moving of pole to storage will vary with the weather, but in no case shall a pole be lifted until 96 hours have elapsed after casting. After removal from the forms the pole shall be painted with a mixture of one part cement and one part sand, the pole being wet before the application of this paint.

Remember that a crack formed in a pole by handling too green can not be healed.

In the storage and shipping of poles 2-inch cleats must be placed between the separate horizontal layers of poles to allow attachment of clamps for handling.

Four standard types of poles are made: One with 7-inch top, 30 feet long, being the standard trolley pole for city construction, either bracket or span; one with 7-inch top, 35 feet long, for interurban trolley lines; one with 8-inch top, 30 feet long, for heavy city service; and one with 8-inch top, 45 feet long, for feeder lines. The standard 30-foot pole weighs approximately 3,200 pounds and costs complete, including all material, labor, and maintenance charges, $12.03 at the yard. This pole is designed to take the place of the steel tubular pole costing about $35.

The standard 7-inch, 30-foot pole has reinforcing as follows: Twisted steel rods placed about 1 inch from the surface—four $\frac{5}{8}$ inch by 29 feet, four $\frac{1}{2}$ inch by 23 feet, four $\frac{1}{2}$ inch by 16 feet, and four $\frac{1}{2}$ inch by 8 feet. The poles with 8-inch tops have the same arrangement of rods, all $\frac{5}{8}$ inch instead of $\frac{1}{2}$ inch. The longer poles have the rods lengthened at the top ends. Altogether the New York State Railways, Utica-Syracuse lines, had some 1,400 of these reinforced-concrete poles in use at the end of 1913 on their various city and suburban lines, and tests made as late as March 12, 1914, showed that the standard types and methods of construction needed no change to give greater strength of permanence.

Concrete-pole tests.—Some interesting tests were reported on concrete poles from Oklahoma City, Okla., and Nashville, Tenn., early in 1914, in regard to solid and reinforced poles and the best placing of reinforcement. Six poles each were tested by the Oklahoma Gas & Electric Co. at Oklahoma City, and the Nashville Railway & Light Co. at Nashville. The concrete for all poles was in the proportions 1:2:3½, and high-carbon square cold-twisted steel bars of 50,000 pounds per square inch elastic limit were used for reinforcing. The rods were bent to insure good bonding. The poles were molded in wooden forms by men experienced in concrete work but not especially trained for pole making, so as to duplicate field conditions. The hollow poles were made with sectional tapered sheet-iron cones.

At Oklahoma City the pull was applied by means of a cable fastened to the pole 6 inches below the top and passing through a block attached to a neighboring gas-tank frame. A coal car was attached to the free end of the cable and loaded with sacks of sand. At the ground line the poles butted against a heavy, rounded-end timber braced against the bank, with another timber, renewed for each test, braced against the butt. At Nashville a cable was attached 1 foot from the top of the pole and passed through a block at the top of a guyed mast. The pull was applied by a hoisting crab and measured by means of a pair of dynamometers. Here the poles were braced at the ground line and concrete footings were placed around the butts. Deflections were measured by means of a rule at Oklahoma City and by rule and plumb bob at Nashville. Poles were tested to destruction in all cases.

The general conclusion was that hollow poles are not successful in resisting shearing forces from the ground line down, as all showed shearing failure in this region. After failure the tendency of the concrete on the compression side was to slide by that on the tension side, causing a shearing action in the side walls. Inasmuch as hollow poles are more expensive than solid ones and are more difficult to make, and as they are not much lighter for equal strength, their use is not advised. Poles having few bars with some butt reinforcement were shown to be preferable.

At Nashville the tests showed that a safety factor of 2 is obtained when 1,200 pounds per square inch unit stress is allowed for 1 : 2 : 3½ concrete and 30,000 pounds per square inch for high-carbon steel. The average calculated breaking load (straight-line formula used) for four hollow poles was 2,375 pounds, and the actual breaking load was 1,557 pounds applied 6 inches from the top. Five of the solid poles had calculated average breaking loads of 3,500 pounds, while the actual breaking load was 3,610 pounds.

Trolley brackets on buildings.—One of the noticeable differences in practice hitherto between trolley lines in American city streets and those of the Old World has been the attachment of trolley span wires by plaques or brackets to buildings in European cities, thus dispensing entirely with poles. One of the leading reasons for this difference has been that in Europe the streets through which many of the trolley lines run are very narrow, permitting only one track and affording no foothold for poles. In America the average streets are much wider, and poles can be planted without any real interference with the travel of pedestrians or vehicles. There is also understood to be an objection in America on the part of fire insurance companies to the plan of building attachment. The statistics of the relative inflammability of European and American buildings would appear to warrant this objection, but it is obvious that better methods of installing and insulating lines would overcome it. During the period 1907–1912 there was a marked tendency in some places to clear the streets of poles and to try out the European method. Two instances may be cited. Under the direction of the board of public safety of Fort Wayne, Ind., a movement has been in progress for some time to remove all unnecessary poles and wires from important streets in the business district, and this is working out in a very satisfactory way both to the property owners and to the Fort Wayne & Northern Indiana Traction Co., which operates the local street railway system. Several years ago the board of public safety made arrangements with the owners of property on Calhoun Street, the principal business thoroughfare, by which the railway company was granted easements to attach its span wires to buildings, thus doing away with the necessity for poles for span wires. Rights were also secured for running feeder wires in some instances underground and in some cases down alleys. As a result, span wires were attached to buildings and poles taken down for a distance of a mile on Calhoun Street, greatly improving the appearance of the street. As a matter of protection to the company, papers were signed by the property owners relieving the company from any liability for possible damage to buildings as the result of strain imposed by span wires. The company was put to no expense for this innovation except the expense of making the change. These span wires were attached to the buildings by means of expansion corrugated iron sleeves, which are embedded in the walls to a depth of about 6 or 8 inches.

The other example is that of the Tri-City Railway of Davenport, Iowa. To eliminate pole construction in front of retail stores, the company has developed a method of attaching span wires to the faces of the buildings. This plan is followed generally where the owner of the building requests that it shall be done. The hole in which the eyebolt is inserted is drilled in the wall of the building with a 2-inch pipe drill at an angle of about 96 degrees and to a depth of from 10 inches to 12 inches, according to the length of the eyebolt. A fire-clay mold is then used, placed so as to hold the eyebolt in the center of the hole and to prevent the melted sulphur which is poured into the hole from running down the side of the wall. After the sulphur has cooled the mold is removed, and the sulphur, which is made flush with the surface of the wall, is then painted. Eyebolts are placed in the columns of brick walls in the same way.

Combination trolley and lighting poles.—Another effort toward the diminution of the number of poles on the streets is seen in the various efforts made to carry street lights on the trolley lines. An excellent illustration is afforded by Niagara Falls, N. Y. The International Railway, of Buffalo, N. Y., recently made an installation of combination lighting and trolley poles on the main street of the city of Niagara Falls under somewhat unusual circumstances. The poles, which were purchased by the city, are provided with slots below the ground line so that if desired in the future the feeders now carried upon them may be placed in conduit below sidewalk level. The material used in the pole construction is 7-inch, 6-inch, and 5-inch standard-weight tubing. The poles were installed on Falls Street in accordance with a plan for lighting which had been under consideration in Niagara Falls for many years and which was crystallized by a comparatively recent offer of the Hydraulic Power Co. to furnish free electric current for the lighting system. Early last June the city asked the president of the International Railway Co. if the trolley poles could not be removed from the street in furtherance of the plan. He consented not only to remove the trolley poles but to place the new poles for the city and to transfer the trolley wires and feeders to them without charge. The work of installation was begun in August, 1913, and was completed inside of three months.

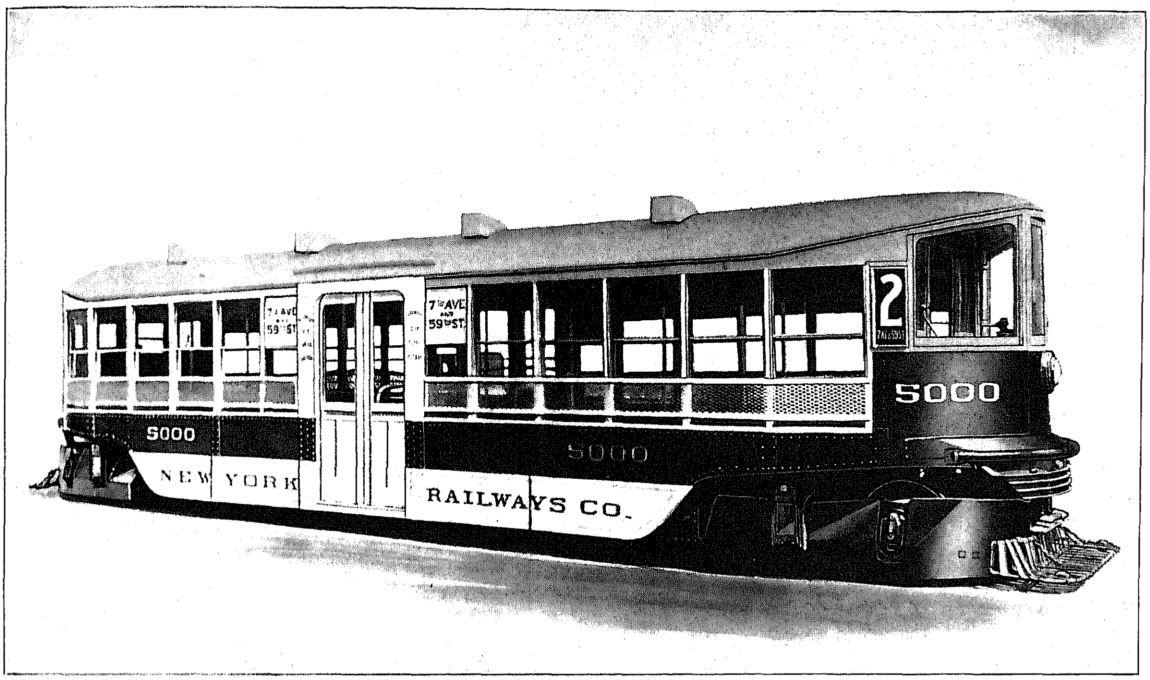
The installation consists of 112 poles, each of which is equipped with a double bracket for supporting a pair of inverted arc lamps of about 800 candlepower each. The poles are spaced at 70-foot intervals, thus giving one of the best street-illuminating systems in the country.

ADVANCES AND CHANGES IN STREET CARS.

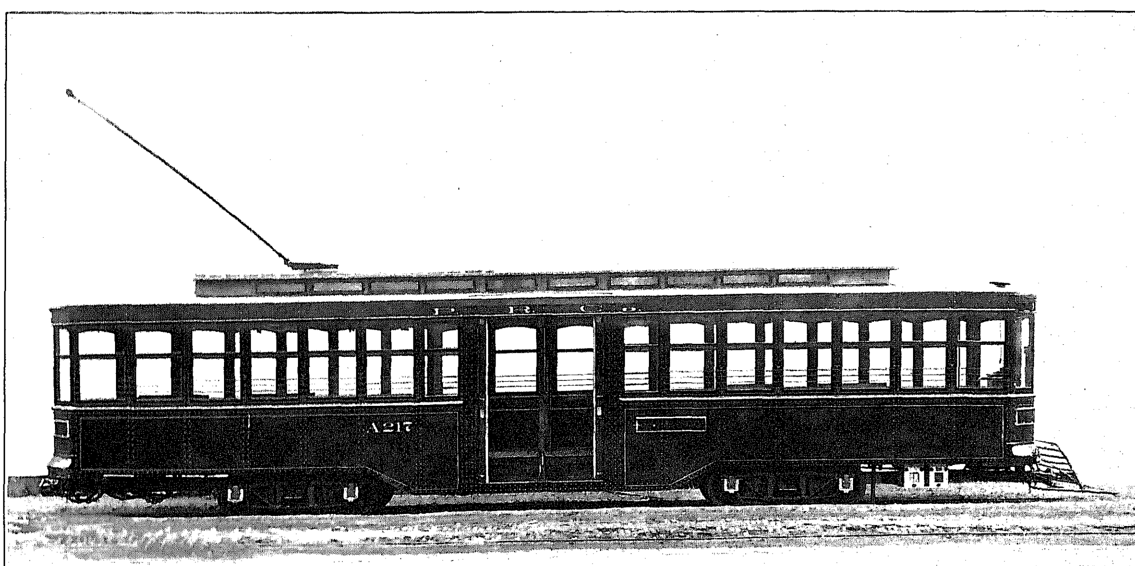
No more startling changes in the street railway industry have been shown in years than those in its cars. In the effort to deal with problems of congestion, low rates of fare, public convenience in entering and leaving cars, the full collection of fares, and safety in operation, an extraordinary number of new types have been evolved, each with its special merits, but many of which must undoubtedly disappear from service. The year 1912 was particularly marked by an outburst of originality in this respect, and probably no previous period in street railway history showed so many innovations. Some of these will be noted. The modern stimulus in car design for city service may be said to have begun with the successful demonstration of the pay-as-you-enter car, which originated in Montreal and was shown first in the United States at the Columbus convention of the American Electric Railway Association in 1906. The prepayment plan may now be considered as a permanent feature of city car design. The developments in 1912 were in the extension of this principle to center entrances, with an increase in accessibility to the car, in greater attention to safety features, and in renewed use of one-man cars. Early in 1912 came first the New York "stepless car" with a body hanging near the ground between the trucks, and then the low center-entrance cars of Brooklyn and Washington and the center-entrance, end-exit car of San Diego. These were accompanied by the "low-floor" car of Pittsburgh, in which 24-inch wheels and small motors eliminated one step and reduced the weight to an unprecedented figure. As soon as the success of the low-level cars of New York and Pittsburgh was assured, the trial of double-deck cars based on these designs became almost obvious, and during 1913 cars of this type were placed upon the street almost simultaneously in the two cities. In the meantime, also, the "near-side" principle, developed during 1911, had been applied to one-man cars, thus supplying a need for light-traffic service which had existed, but had been neglected, since the bobtail horse car disappeared. During 1912 also there was under construction and trial the most extraordinary development of all, the "articulated" car of Boston, consisting of two old single-truck cars set end to end and flexibly connected by a low-hanging vestibule with center side doors. Last among the radical designs of the year came the storage-battery "stepless" type, a four-wheeled car without a truck frame and of extremely light weight.

With one exception, all of the center-entrance cars were developed primarily to provide easier access for passengers by a reduction in step heights, with the exceedingly important indirect benefit of decreasing the time of passenger movement, thus permitting faster schedules. Most of the cars mentioned have demonstrated their obvious advantages, namely, increased seating capacity, greater accessibility to all seats, and increased safety of operation.

The articulated car is primarily adapted to the rebuilding of old equipment, and provides an answer to the question as to what disposition can be made of old rolling stock rendered obsolete by the introduction of the new types. The double-deck designs of New York and Pittsburgh also have not apparently arrived at the stage where their merit insures a general adoption. Climate comes in to some extent in determining their field of use. The Pittsburgh car, however, has been reported to be a thorough success

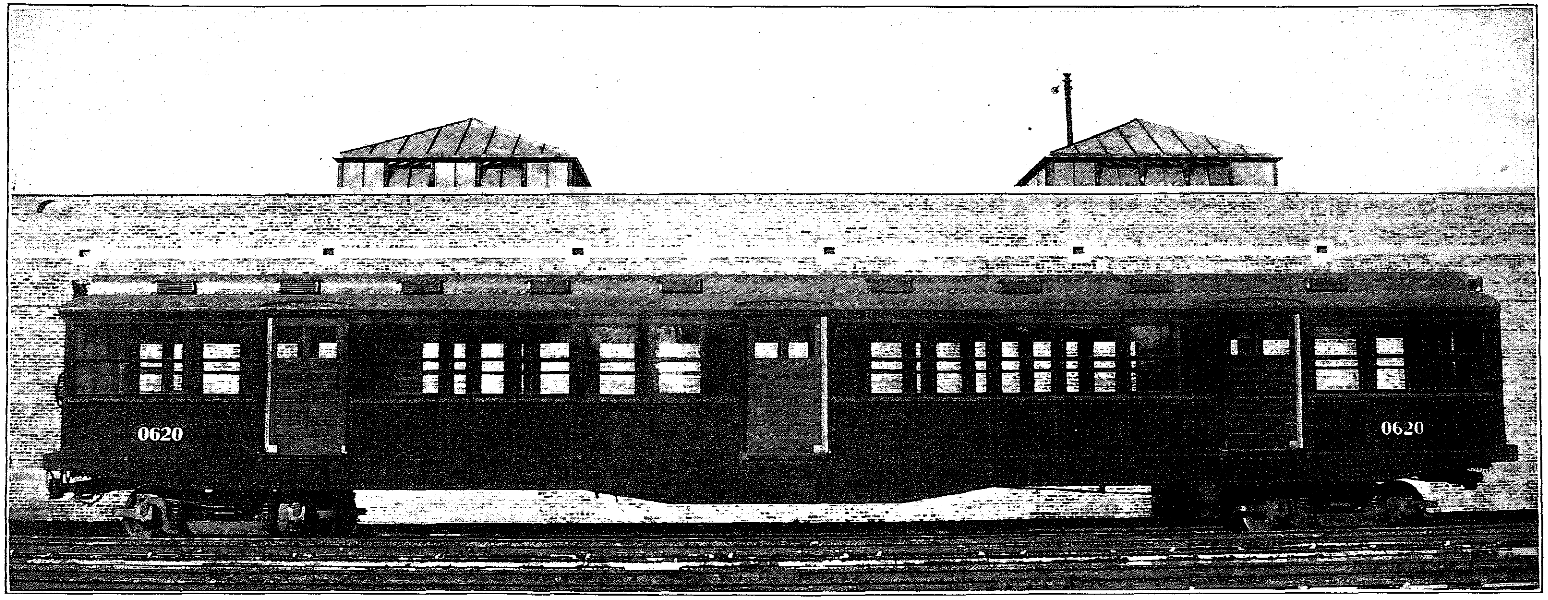


CENTER-ENTRANCE, STEPLESS CAR, NEW YORK RAILWAYS CO.

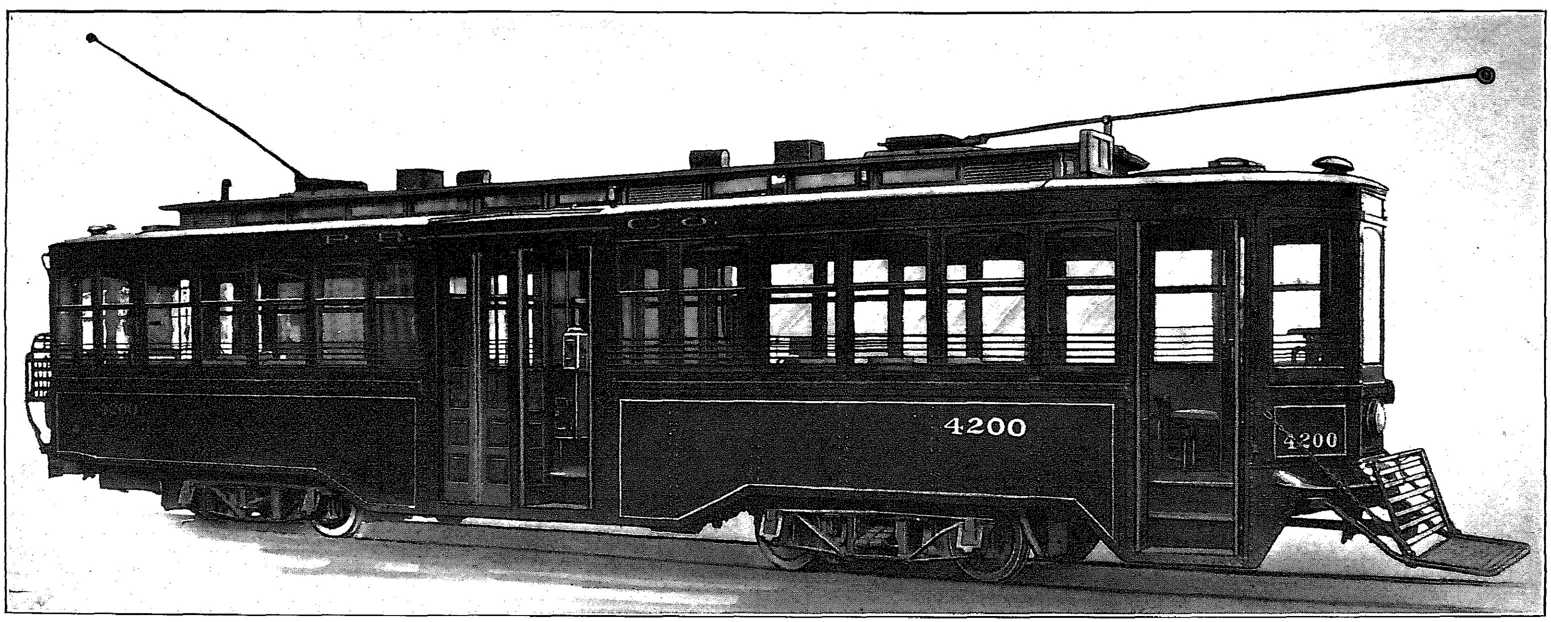


LOW-FLOOR CAR, PITTSBURGH RAILWAYS CO.

(Face p. 356.)



ALL-STEEL, SUBWAY CAR WITH THREE SIDE ENTRANCES, BOSTON, MASS.



CENTER-ENTRANCE, END-EXIT, SMALL-WHEEL CAR, PITTSBURGH RAILWAYS CO.

for handling crowds going to parks or games and caring for rush-hour traffic from factories; and a duplicate of the New York car has been ordered for Columbus, Ohio. Both double-deck cars are, of course, of recent construction, and the opportunity for trial has been limited.

The new types of cars for interurban service and for heavy electric traction are less numerous and less divergent from previous types. The steel cars of the Cambridge Subway probably show a greater departure from generally accepted standards than any of the other large cars of the year. They are equipped with three side doors, and the usual platforms, bulkheads, and platform doors have been eliminated. One of the doors is located at the center of the car, and the other two are approximately over the trucks. This plan divides the car into four sections and gives, in the longer car, the same effect as the center entrance so notable in the new designs for city service.

In general, the use of steel for car bodies has shown a marked increase. All except two of the new types of city cars have depended upon the girder effect of the side sheathing between belt rail and sills to support the load, the strains being carried around the doorway by heavy reinforcement, and it is manifest that this construction is to be perpetuated. In fact, with the existing demand for light-weight cars, such a form of steel construction seems to be obligatory, as the low records for weight established during the year were obtained through its use. For the same reason it would seem that the adoption of wheels of small diameter would become general in slow-speed service, as their practicability has been thoroughly demonstrated.

Double-deck Pittsburgh cars.—These cars in use on the Pittsburgh railways are intended not only for special service to parks, ball games, etc., but for regular runs on one of the city lines. On this line, however, 75 per cent of the passengers are loaded at five points in the central part of the city. Contrary to the somewhat prevalent belief that the double-deck design involves an enormously high first cost, the quotations which were made for the five cars were found to be exceedingly low considering the increase in seating capacity. In fact, the actual price paid for each amounted only to approximately $1,500 more than the cost of a standard single-deck car.

The cars are carried on small wheels to permit the use of a low main floor which is only 28¾ inches above the rail. The center portion of the main floor is depressed to form a well from which the stairs extend to the upper deck and which also provides space for separate entrance and exit doors. The two stairways are located on both sides of the car, but face in opposite directions, the exit stairway having its floor alongside of the front doorway, which is used only as an exit. The stairway for ascending passengers is, in consequence, on the opposite side of the car from the door which is used as an entrance, and the fare box, behind which the conductor is stationed, is near the foot of this stairway. This arrangement provides a loading space having a length of approximately three-fourths of the width of the car, and gives room for about eight entering passengers between the door and the fare box.

The seats on the upper deck are longitudinal and are arranged back to back in the center of the car, the space underneath the seats providing a clear head room for the first floor of 6 feet ½ inch. These seats are curved outward at the ends of the car so that head room for the motorman on the lower deck is provided across the full width of each end. In consequence, the motorman can stand erect on the lower deck without having his movements restricted.

The over-all length of the car is 47 feet 2 inches, and the width is 7 feet 10 inches, both dimensions being approximately standard with the newer single-deck cars of the Pittsburgh railways. This makes the cars shorter but wider than the original, which was built in the railway company's shop by fastening two small cars end to end and putting a second deck over them. The trucks are set on 22-foot 2-inch centers, and each end of the car is in consequence almost exactly balanced over one of the trucks. The over-all height is 13 feet 8 inches, 9 inches less than that of the original, and the clear heights for the upper and lower decks are, respectively, 6 feet and 6 feet ½ inch. The head room at the central wall is 6 feet 3 inches.

The center part of the roof is made 4 inches higher than at the ends, since at the middle section of the car, which is occupied by the well, it is necessary to have a clear head room of at least 6 feet over the full width of the car for both decks. Except at the central well, however, this is not necessary, as the clear head room has to be maintained only in the aisles, and at the sides of the upper deck the floor is depressed 4½ inches to form a walking space in front of the longitudinal upper-deck seats. The depressed ends of the roof have been provided in order to permit the trolley pole to swing out over the edge of the roof on a curve under a low bridge, and also to permit the installation of roof ventilators without adding to the over-all height of the car.

Practically the whole side of the car is designed to act as a beam and the entire weight of the car is supported by this, no underframing being used outside of the two center sills for transmitting pushing and pulling strains. The portion of the car siding which carries out this beam action extends up to the window sills on the second floor. The body bolsters which transmit the load from the sides to the truck center plates are made up of pressed shapes to form a box girder. The center sills, which serve only as a means to absorb pushing and pulling strains, are made up of two 4-inch channels set with the flanges vertical. At a point on either side of each bolster these two channels diverge, extending at a 45° angle to the ends of the bolsters to take up any tendency of the frame to rack. In the center portion of the car, where they are again brought parallel and close together, they are bent downward under the central well and assist in supporting its floor. Floor beams complete the framing.

The seats on the lower deck are in general transverse, and those on the upper deck are set longitudinally to provide head room in the aisles for the first story. Additional seats are, however, provided whereever space for them exists. Thus on the lower deck two semicircular seats for five passengers each are placed at either end of the car and four single seats next to the well. Four longitudinal folding seats are provided in the center well, of which two, seating two persons each, are located on the blind side of the car opposite the doors. The other two, one alongside each stairway, seat three passengers each, but only one of these seats is used at one time. The semicircular end seats at the extreme ends of the car are stationary, and the one which is at the rear of the car is used to seat passengers, the one at the front being used to provide a space for the controller and brake handles, as described later.

On the upper deck, in addition to the longitudinal seats, there are two transverse seats, each seating two persons, at the ends of the stair wells. These, together with the longitudinal seats, provide a seating capacity for 56 persons on the upper deck, and as the lower deck will accommodate 54 passengers, the total seating capacity of the car is 110. The weight of the car completely equipped is 38,700 pounds, or only 352 pounds per seat.

The separation of the entrance and exit doors by a distance of approximately 7 feet has been found to be very effective in separating incoming and outgoing crowds of people, and accounts to a considerable extent for the rapidity with which passengers have been handled.

One of the schemes for avoiding delay in unloading passengers from the upper deck is the elimination of the usual push buttons from that floor. There is, however, a push button at the head of the exit stairs, and signs are prominently displayed to call attention to its location. Upper-deck passengers are therefore required to be ready to descend the exit stairs before they can signal the car to stop, and, as both the motorman and conductor control the exit door and see the feet of any descending passenger, the chance of carrying anyone past his destination is slight.

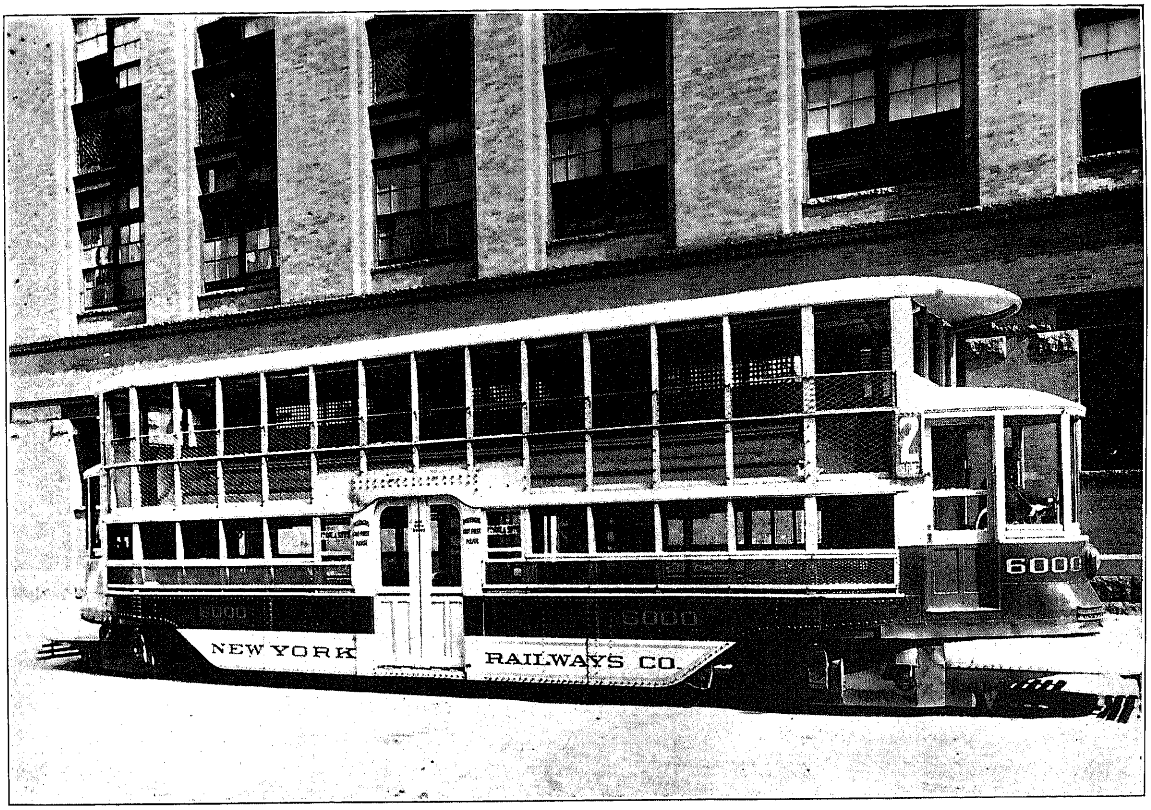
The depressed portion of the lower deck which forms the center well reduces the height of the step from the ground into the car to 13¼ inches. From the doorways there is a slight slope upward to the center line of the car amounting to about 1½ inches, formed by gradually increasing the thickness of the floor strips, a safety tread being provided at the edge of the step. From the well to the main floor of the lower deck there is a step of 12 inches, and a short ramp 2 feet long gives an additional rise of 2 inches, bringing the main floor to a height of 28¾ inches above the rail. Access to the upper deck is effected by a series of eight 9-inch steps which start from a small landing 5¾ inches above the floor of the well. These stairs are restricted in width to 18 inches in order to prevent any possibility of double lines of passengers either ascending or descending, as the fact that the stairs are used only in one direction obviates any necessity for crowding or passing by passengers while on them. Passengers thus have an opportunity to use handholds on both sides of the stairs if the necessity arises, and this minimizes any tendency toward interior accidents due to the presence of the stairs.

The doors are pneumatically operated by the system which has been made standard in Pittsburgh, except that owing to the restricted headroom the apparatus has been reduced in size so that the mechanism takes up no more space than the channels which support the floor. With this device each doorway is provided with two doors, each one of which is equipped with roller supports and guides to define its movement. At the side of the door near the doorpost there is a pin sliding in a guide extending straight inward from the doorpost, so that the outer edge of the door is compelled to travel straight in and out. At a point about one-third of the width of the door from the other edge is another pin which slides in a straight groove, making an angle of about 30 degrees with the plane of the doorway, and this compels this edge of the door to travel across the doorway as would a sliding door. The result of the combined movement of both ends is to make the door as a whole slide into open position around a sharp curve, taking its open position at right angles to the doorway and in line with the doorpost. The two doors in each doorway are mutually operated by means of a simple bell-crank arrangement.

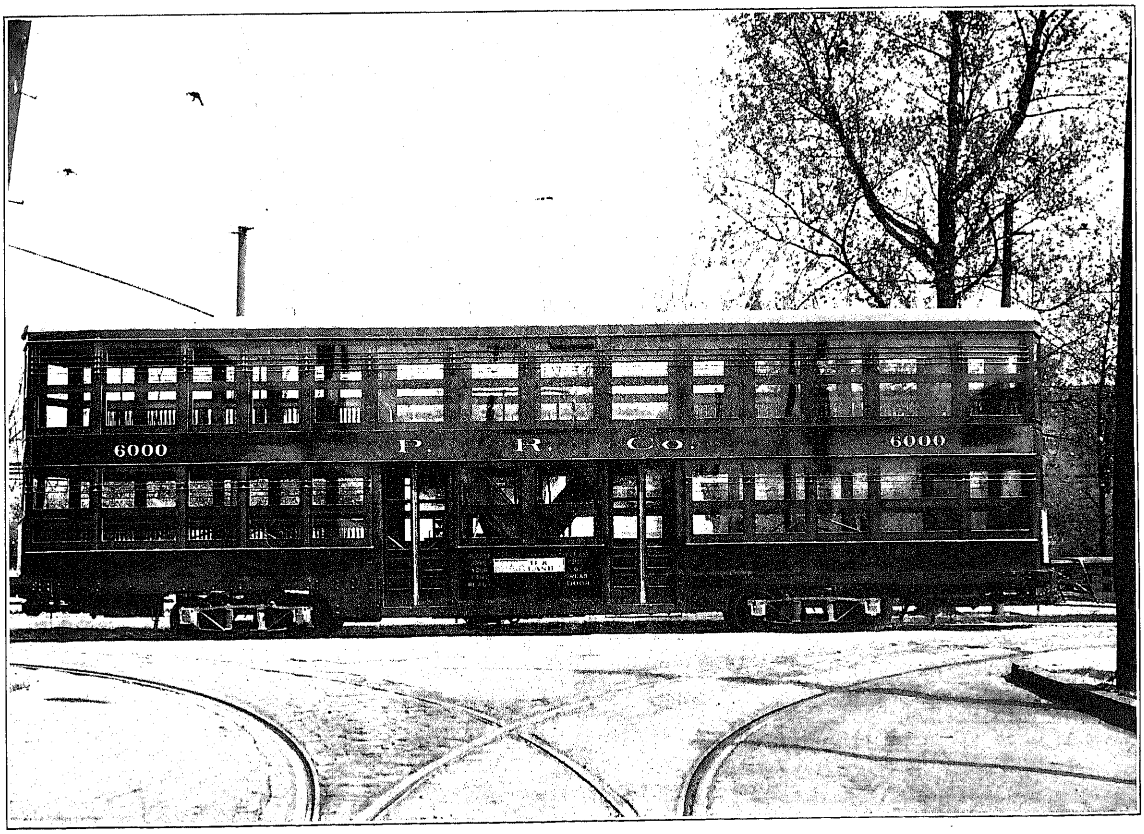
The car is equipped with the "low-floor" type of truck with 24-inch wheels and small motors. Four motors are used, and for their operation a novel form of control has been developed. The master controller is so small that it is placed under the semicircular end seat which is located at each end of the car. Passengers sit immediately over the controller, so that no space is lost on account of its presence at the rear end of the car. When the controller handle and brake handle are removed from their shafts, no space is occupied outside of the vertical partitions installed on the end seats and which really serve as spacers to prevent any passenger from occupying more than a fair share of the seat.

Another novel feature of the car is the provision for keeping all parts of the trolley pole and harp below the high point of the roof, which enables the trolley to pass any overhead structures under which the car itself will

CENTER-ENTRANCE DOUBLE-DECKED CAR.

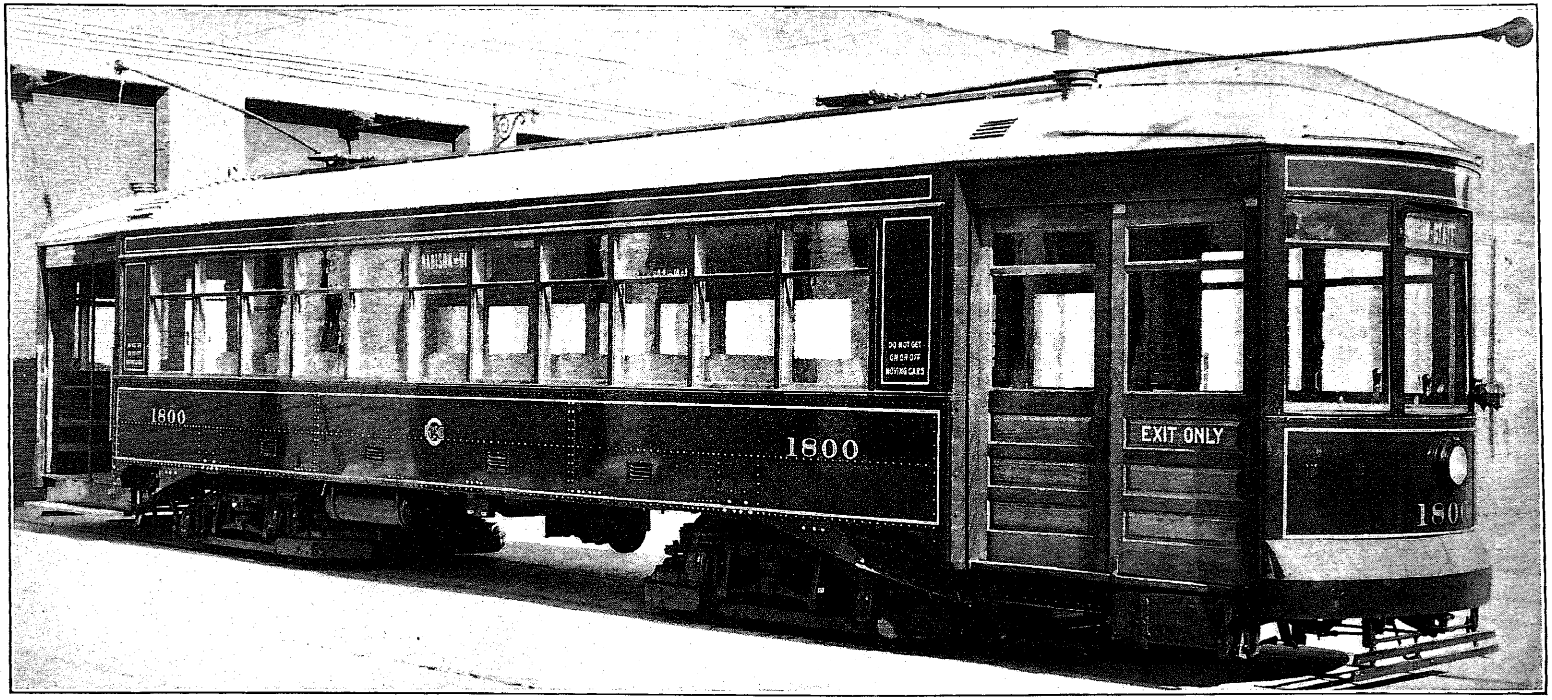


NEW YORK RAILWAYS CO.

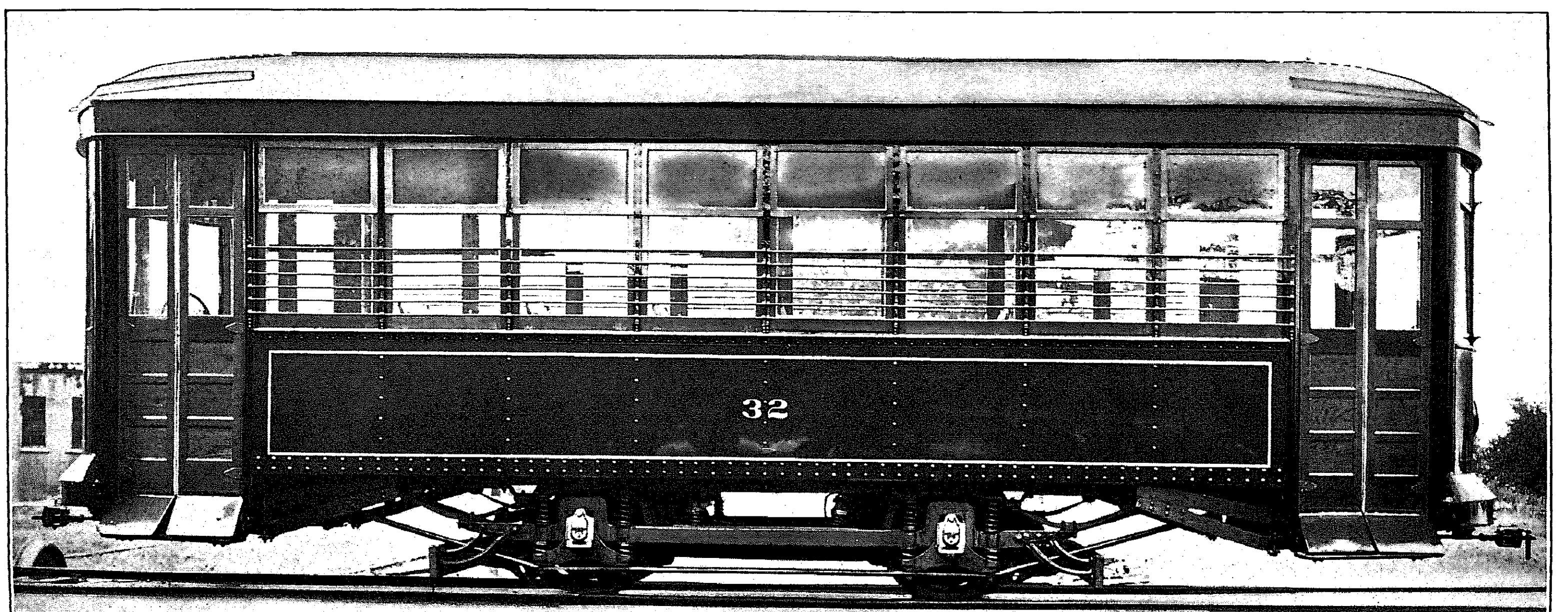


PITTSBURGH RAILWAYS CO.

(Face p. 358.)



STANDARD END-PLATFORM CAR FOR CITY SERVICE, CHICAGO, ILL.



SINGLE-TRUCK PAY-WITHIN CAR FOR SERVICE IN SMALL TOWNS, MERIDIAN, MISS.

go. This is effected by mounting the trolley harp and pole in a depression along the center line of the roof, which extends from a point slightly ahead of each truck center to the end of the car. As this depression follows the center line and is only 2 feet 6 inches wide, it does not decrease the head room except within a space extending over the longitudinal seats of the upper deck. In this space, of course, no necessity exists for full head room, because the passengers have no chance to stand upright when they are under it.

Stepless double-deck cars in Columbus, Ohio.—The street railway situation in Columbus differs from that in any other American city in having only one street along which there is traffic congestion. Into the electric railway cars that traverse this street there crowd during the rush hours almost all the persons in Columbus who want to ride to or from their homes and places of business.[1] During the morning and evening rush hours, traffic congestion in High Street throws all the traction lines of the Columbus Railway, Power & Light Co. off schedule, since 10 out of the 16 routes operated by the company converge on that thoroughfare through its busiest section—Broad Street to Long Street—a distance of only two blocks. In an effort to relieve this congestion, several years ago, the company got permission from the municipal authorities to reroute some of the lines so that they traversed the next parallel streets east and west of congested High Street. The riding public, however, had become so accustomed to "taking the High Street cars" that it refused to violate traditions and declined to patronize any other line. So the relief plan was abandoned. The situation which confronts the company has become more serious each year. Two-car train operation was recently tried, but this did not prove satisfactory, because of delays due to long stops. Again, the operating expenses of the two-car plan were considered too large, since, with seating capacity for only 80 passengers, the train required a crew of from three to four men to operate it. The Columbus Railway, Power & Light Co. operates under a franchise which demands next to the lowest unit fare charged by any company in the country. It is obliged to furnish eight tickets for a quarter, with free transfers. It became imperative, therefore, to provide a car having the largest carrying capacity, coupled with the greatest degree of efficiency; and the low-level, stepless, double-deck car was decided upon as the type which most nearly met the requirements.

The reasons for choosing double-deck operation are contained in the following comparative table, which contrasts the double-deck car with other types in respect to operating expenses, initial cost, and carrying capacity.

[1] Electric Railway Journal, Mar. 14, 1914.

COMPARISON SHOWING COST AND EFFICIENCY OF DIFFERENT TYPES OF OPERATING UNITS.

	Double-deck car.	Single-motor car.	Two-motor cars with multiple unit control.	Single-ended two-car trains, both motor cars.	One motor car, one trailer, stepless.
Cost of equipment (estimated)	$6,500	$4,903	$9,933	$8,773	$7,203
Seated passengers	83	40	80	80	100
Seated and standing passengers	171	100	200	200	210
Total weight without passenger load, pounds	46,000	35,773	71,546	68,209	61,773
Depreciation per train-mile, cents	1.100	0.830	1.681	1.485	1.219
Cost of energy per kilowatt hour, cents	1.602	1.144	2.288	2.038	1.976
Maintenance per mile, cents	2.058	1.470	2.940	2.940	2.940
Platform wages per mile, cents	5.227	5.227	7.841	7.841	7.841
Total cost per train-mile, cents	11.121	9.526	16.483	15.835	15.232
Cost per passenger capacity per train-mile, cents	0.0650	0.0952	0.0824	0.0792	0.0725

The contrast with the single-ended combinations does not mean much so far as Columbus is concerned, since there are very few loops there. It is only when loops are numerous that this scheme of operation can be used economically, because without loops annoying delays result from switching movements at terminals.

It will be noted also that the wages paid the conductor and motorman on the new double-deck car are the same as those for the single-motor cars and represent a much smaller outlay than the sums paid to operators of the other types. The cost per passenger capacity per train-mile is lower than that for any of the other contrasted types.

Selection of the double-deck car was also influenced by these economic features: Additional safety to passengers by elimination of dangers incident to entrance and exit; greater convenience in entering and leaving car; improvement in working conditions of motormen and conductors; better sanitation through scientific ventilation; elimination of dangers due to premature starting of cars, since they can not start until the doors have been shut; greater facilities for passengers who want to smoke; traffic congestion reduced by increase of almost 100 per cent in carrying capacity per foot of street occupied; decreased maintenance and operating expenses in the handling of passengers.

The new double-deck car is 45 feet 6 inches long over all, having an extreme width over the belt rails and eaves of 8 feet 3 inches. The over-all height from top of rail is 13 feet 2½ inches. The trucks are at 29-foot centers. The framing throughout is of rolled-steel or pressed-steel sections.

The lower-deck floor extends from the center of the car to the edges of the semicircular seats at each end, rising slightly from the center to clear the truck axles. The space underneath the end and cross seats is not floored, and the wheels and truck frames extend up under these seats. This arrangement permits the truck to swing sufficiently to pass around a curve with a minimum radius of 37 feet.

The upper deck extends only between the bulkheads which separate the motorman's cabs from the seating space of the lower deck. The stairways are at the extreme ends. Each stairway extends up with three steps to a platform and branches to the right and left with four more steps to reach the walkway of the upper deck. The stairways are provided with hand rails.

The walkway of the upper deck extends entirely around the car except at the stair wells and is 5 feet $1\frac{1}{2}$ inches above the floor at the semicircular end seats of the lower deck. The floor at this point is 19 inches above the rail, and is reached by a ramp from the floor level at the entrance doors. The floor at the entrance is 11 inches above the rail. The upper walkway extends over the longitudinal seats of the lower deck, and, since for this reason it is unnecessary to have it high enough to permit a man to stand erect, it is only 6 feet $8\frac{1}{2}$ inches above the track rails. The seats on the upper deck are placed at the proper elevation to provide ample head room along the center aisle of the lower deck, and are so high that it is necessary to provide a footboard along the full lengths of the seats, which, in giving space for passengers' feet, keeps them from blocking the walkway.

The upper deck is closed in winter and is opened during the summer months by taking out the removable sash and sections of sheathing. The ends of the upper deck are protected against the weather by extension of the first-floor bulkheads, and are fitted with outward-swinging windows.

Safety treads are used at the center doorways and at the doorways of the motorman's cabs, and narrow sections of this tread are used to face the stairway steps and the front edge of the upper-deck footboards.

The car is equipped with maximum-traction trucks of the low-bolster type with outer bolster bearings outside of truck side frames. The driving wheels are 33 inches and the pony wheels 18 inches in diameter. The truck wheel base is 5 feet. The brakes are the inside type. Each truck is designed to receive one outside-hung motor.

The seats of both decks are longitudinal except for the semicircular seats and the two cross seats at each end of the lower deck. The seats on the upper deck are set back to back, and the feet of the passengers seated on them are almost directly over the heads of the passengers who are seated on the longitudinal seats of the lower deck. The latter seats extend from the center entrance space to the end wells of the car. At the end of these seats are two permanent cross seats. The semicircular end seats extend from the cross seats around the end wells. All seats are rattan.

On the basis of 17 inches per passenger, the upper deck will seat 42 passengers and the lower 41, making a total of 83. It is estimated that the car will accommodate 171 seated and standing passengers. The total weight of the car completely equipped is approximately 46,000 pounds, giving a weight per seated passenger of 554.2 pounds and a weight per passenger, standing and seated, of 269 pounds.

The entrance and exit are by the center side doors. These doors are made in halves. The total door width is 50 inches, divided into two passages by a rail so that two streams of passengers may leave or enter the car at once. The doors are electropneumatically operated and are controlled by the conductor.

The entire center of the car for a width of 50 inches is devoted to receiving and discharging passengers. The conductor is seated on a folding seat along the unused center door, and before him is a swinging change desk. Space for 10 passengers is provided on the loading platform. Entering passengers line up before this desk, and after depositing their fares in the fare box pass on toward the seats and stairways at both ends of the car.

A forced-draft ventilator system is provided for the ventilation of both decks. The foul air is drawn through ventilators which are placed along the center lines of the ceilings of both decks and is carried along longitudinal ducts to the motor-operated fan at the end of the car, where it is discharged. The duct for the lower deck is carried between the seat backs of the upper deck, and at the center of the car a riser connects this duct with the one running along the roof of the upper deck. Heat for the car is supplied by electric heaters, 14 being installed on the lower deck and 12 on the upper deck.

New street-car types in Chicago.—The cars purchased in 1912 by the Chicago City Railway Co. were the first inclosed double-end motor cars to be placed in service there. The new cars in general conform to the old-type standard cars and to the over-all dimensions laid down by the board of supervising engineers. They provide a seating space for 54 passengers, equivalent to that of the near-side cars.

The general dimensions of these new cars are as follows:

Length of car over body corner posts, 32 feet 8 inches.
Length of car over bumper, 48 feet.
Width of car over all, 8 feet 6 inches.
Width of car over posts at belt rail, 8 feet 5 inches.
Height of top rail to top of trolley board, 11 feet $7\frac{1}{8}$ inches.
Truck centers, 22 feet.
Diameter of driving wheels, 34 inches.
Diameter of pony wheels, 22 inches.
Wheel base of truck, 4 feet 10 inches.
Height of first step above top rail, $13\frac{1}{2}$ inches.
Height from first step to platform, 12 inches.
Height from platform to body floor, 10 inches.
Total seating capacity, including vestibules, 54.
Estimated weight complete, 40,000 pounds.

The design of the bottom framing of these semisteel cars includes departures from the usual designs employed in former Chicago cars. Probably the most marked of these are the side sills, which are inverted fish-belly type girders built of $\frac{3}{16}$-inch steel plate and angles and over-trussed. The top is reinforced by a 2-inch by $\frac{5}{16}$-inch flat bar, and the bottom by a 2-inch by 2-inch by $\frac{1}{4}$-inch angle. Three openings, 6 inches by 4 inches, cut in the three center panels of these side sills, provide for air-duct connections to the cross-seat heaters in the car. In addition to the plate-girder side sills, the sides of the car are over-trussed by $2\frac{1}{4}$-inch by $\frac{3}{8}$-inch steel bars applied on the angle-iron posts 2 feet $10\frac{3}{4}$ inches above the bases of the side sills and anchored at the girder ends.

Another unusual feature in the design of the bottom framing is found in the cross sills. These are arched trusses formed of two $1\frac{1}{4}$-inch by $1\frac{3}{4}$-inch by $\frac{1}{4}$-inch steel angles, the upper one being horizontal and conforming to the car floor, and the lower one forming an arch from the bottoms of the side sills to the level of the upper member at the center of the car body. These angles are fastened together at the center and the side sills with $\frac{1}{4}$-inch steel plates. This particular design of cross sill is employed because it gives maximum clearance for electrical conduits and other car equipment underneath the center of the car body, and bending tests demonstrate that it is equal in strength to a cross sill of a uniform section carried between the side sills.

The car body is fitted with 13 window openings on each side, the upper sashes of which are stationary and arranged in a continuous frame. All lower sashes are arranged to raise vertically to the level of the continuous bottom rail of the upper sashes. In addition to these, storm sashes are provided at all side windows of the car for use in extremely low temperatures. The sashes are single, two-pane, and conform in shape to the body sashes, being held in place by three brackets and a lock mounted on each post.

Each bulkhead of the car contains one swinging door and one sliding door, the standard for all surface cars in Chicago. The location of these doors, however, is somewhat different from the present standard, in that the stationary portions of the bulkhead are at the sides of the car instead of in the center. By this arrangement it is possible to give additional length to the four longitudinal seats in the four corners of the car body. In conformity with the general practice in surface railway car design in Chicago, one side of the vestibule is equipped with a sliding door, fitted with manually operated mechanism, which also raises and lowers the step. The opposite side of the vestibule, however, represents a new departure for Chicago in that it is fitted with folding doors and steps divided into two groups. The two exit doors are hinged to the body corner posts, and the two entrance doors are hinged to the vestibule corner posts. Each pair of doors is equipped with a hand-operating device, which also raises and lowers the steps. In order to make the operation of these folding doors and steps as easy as possible, the operating mechanism is fully equipped with ball bearings.

Other innovations in the vestibule equipment on the new cars include a light signal system connected with the platform folding doors, which indicates to the motorman whether the doors are in the open or the closed position. In earlier cars the motorman's and conductor's seats have been separate from the hand rail dividing the entrance from the exit aisles. The specifications for the new cars provide that these seats are to be fastened to the platform railings by pivotal brackets and made adjustable for height. When the seats are not required, they may be folded and swung over to one side clear of both aisles.

Each car is fitted with 18 cross seats. The arrangement of the doors in the bulkheads provides additional length for the four longitudinal corner seats, but in order that the aisles may be clear at the rear end of the car, all four of these longitudinal seats contain collapsible sections adjoining the bulkheads. Two collapsible wooden seats are also installed in each of the vestibules. One of these seats provides for four persons and occupies the space along the closed folding doors in the front end of the car, and the second seat is for two persons and occupies the space against the closed and locked swing door in the bulkhead.

No fewer than 200 low-step, double-end, arched-roof motor cars have also been added to the rolling stock of the Chicago Railways Co. A careful check of all the weights of material entering into the construction of the new two-motor cars shows that a reduction in weight of more than 10,000 pounds has been made as compared with the 1911 arched-roof four-motor car, despite the fact that the new cars are 3 feet 5 inches longer than the 1911 type, being of 48 feet 5 inches as against 45 feet over-all length.

The aisle width in the finished car is 25 inches between end-seat plates, but further effective aisle width was obtained by offsetting the seat backs 2 inches. The wide, comfortable seats are $36\frac{1}{2}$ inches over all, and this length was obtained by making the sides of the car as compact as possible. The inside finish is set back of the post line, thus reducing the thickness of the sides of the car body to $1\frac{7}{16}$ inches, and adding effective width to the seats. The floor construction is also quite unusual. The floor is built of a single thickness of $\frac{7}{8}$-inch matched flooring under the seats, and the aisle is doubled in thickness by wooden floor mats. The single floor is insulated with a heavy two-ply felt paper, cleated up with light wooden strips. Over this paper a heavy coat of paint has been applied to increase its waterproof qualities and provide extra insulation.

Other construction features in the car body include a careful study of the installation of the auxiliary equipment on the under side of the car floor. The location of each item was selected after a careful estimate of the moments so that the complete installation would balance around the longitudinal and transverse axes of the body. The small deflecting gutter over the entrance and exit doors was formed by setting a strip of poplar in a heavy coat of white lead on top of the canvas roofing.

Low steps in double-end cars require a very careful study of every item affecting their height if the minimum is obtained. This was especially true of the Chicago Railways cars, which have a total height at the center of the car floor of 37 inches above the rail. The height of the first step above the rail is 13 inches and that to the platform is 11 inches. A 10½-inch riser at the threshold plate and a 2½-inch ramp from the bulkhead to a point in the floor above the bolsters, a distance of 5 feet, makes up this total height. The slight pitch of the ramp is scarcely noticeable to passengers entering or leaving the car. To obtain this over-all dimension, it was also necessary to take advantage of minimum over-all dimensions in the design of the trucks, motors, and bolsters. By the use of a 32-inch driving wheel instead of the 34-inch wheel which has been standard on the Chicago Railways, an additional reduction of 1 inch in height was obtained.

An interesting feature in the construction of these new cars is the practical application of safety principles in their design. A number of new departures in the design of the air-brake equipment were included to accomplish this end. One of the innovations in connection with this air-brake equipment is an emergency valve which makes it possible for the motorman to get an emergency application at the brake valve, the air being taken directly from the reservoir. At the same time the brakes are applied and sand is automatically deposited through air sanders. In addition to these, a conductor's valve is placed in each vestibule so that an emergency air application may be made by him if necessary.

A number of safety appliances were also incorporated in the brake apparatus under the car body. In case the pin connections break, the air-brake apparatus is left operative, as the loop or boxed-over end of the rod holds it in position.

Following the standard Chicago practice, a single sliding door is provided on the exit side of the front platform, connected to the step, which raises when the door is in the closed position. The sliding door does not recede into a pocket, the partition forming it having been removed, so that the exposed door slides along the side of the vestibule. A two-piece folding door on the opposite side of the platform opens and folds against the controller. It differs from the doors used in the older types of cars, which were four-piece. Another departure consists in a long slatted seat, so placed and connected that when the door is in the closed position the seat is lowered and the step is raised. One end of this seat is hinged to the front of the vestibule, and when it is raised to clear the doors it actuates levers which lower the steps.

The conductor's and motorman's rails are about the same as those on the platforms of the older cars. The center leg of the rail is equipped with a bayonet lock in the bottom casting. This locks it into the floor socket when it is in position and it may be unlocked by raising a sleeve set on the leg just below the rail. The other two legs are made with partial flanges at the base so that they will hook into slots in the sides of the floor sockets when the rail is in position. In order to engage the locks, it is necessary to tilt the rail to insert the two outside legs, which when raised to a vertical position are held rigid by the bayonet lock on the center leg. The hand-brake staff is set close against the front of the vestibule, and the handle is designed so it can be fastened against the vestibule to give more platform space.

Each side of the car body contains 11 windows equipped with brass bottom sashes and arranged to raise into pockets provided at the top of the window opening. The top sash is built of wood and is continuous from end to end of the car body. The fact that it is continuous and is permanently attached to each post by screws materially increases the stiffness of the car sides. In order thoroughly to insulate these windows against extremely low outside temperature, storm sashes are provided. Each side of the car is fitted with three sections of three windows each and one section of two windows. The new wooden storm sashes, which weigh 15.7 pounds per window as compared with 18.7 pounds for the old metal sashes, represent a reduction in weight of 17 per cent. They are fastened to each post with four screws, three of which are used to hold the window guards. These screws are set into brass castings fitted into pockets in each post. This manner of fastening these sashes makes them much tighter than the old metal sashes, which were attached by locks and clamps.

The curtain rolls are exposed so that the curtains may be cleaned on both sides as they pass over the rolls. They are set into shallow recesses at the top of the window openings, and the curtain fixtures are covered with neat brass caps. Another simple innovation which aids materially in cleaning the cars was included in the manner of installing illuminating signs. These sign boxes in the vestibules and at the center windows in the car sides are hinged at the top and fastened at the bottom with catches so that they may be released and swung away from the glass to permit cleaning. In the old cars the sign boxes were permanently installed, so that it was possible to wash the glass only on the outside of the car.

The mechanical department of the company, in selecting the interior finish of the car body, endeavored to make it as light as practicable to increase the efficiency of artificial illumination. Accordingly, the head lining was finished in light buff, and the trim was finished in natural cherry. This improved the car illumination 50 per cent over the old pea-green head lining and stained-cherry finish. An actual test of the average illuminating qualities of the new as compared with the old car finish shows that the illumination at the aisle seat of the new car is 4.34 foot-candles as against 2.78 foot-candles for the old car. Birch finish was used in the first 25 cars for test purposes. It not only was much cheaper than cherry, but at the same time was just as satisfactory for interior finish. Owing to the tendency of birch to warp, however, it was necessary to use cherry for the door stiles and crossbars. The panels in these were made of birch and the two woods blended almost perfectly.

Chicago Elevated all-steel cars.—At the close of 1913 the Chicago Elevated Railways placed an order for 128 all-steel arched-roof cars, which may be regarded as the latest to be employed in that class of work. A fireproof car was desired which, at the same time, would not weigh more than the heaviest cars now used by this company. This design was also considered more economical from a maintenance standpoint, as it was believed that this type of car would have a much longer life than those of composite construction. For the previous four years the growth of the elevated railways was limited by the capacity of the Union Loop. This could accommodate 700 cars an hour, and about this number were being looped by the four divisions of the elevated railway system, then owned by as many different companies. About three years ago these were put under a single operating management, following which negotiations for their merger with the surface lines were begun by the city council. In the latter part of 1912 these negotiations were broken off, and in the summer of 1913 the Elevated Railways applied to the city council for the right to rearrange the loop structure to permit through routing of cars. This request was granted, with the result that the capacity of the loop was increased from 700 to 1,200 cars per hour.

From 1909 to 1912 the passenger traffic had increased but little. Consequently, there was no necessity for additional rolling stock. However, following the inauguration of through routing, which was accompanied by the introduction of universal transfers, the traffic showed an increase of more than 3 per cent in one month. In order to meet the abnormal growth, as well as future demands, the new all-steel cars were purchased. The old type of elevated railway car had only two doors, which were insufficient to expedite boarding and alighting to a point where schedules would not be retarded during the present rush hours. To meet this difficulty, the new cars are equipped with three doors, one at each end of the body and one in the center. Their adoption necessitated the use of longitudinal seats, which, however, permit a larger standing load.

The principal dimensions of the car body are as follows:

Distance between center of trucks, 33 feet 8 inches.
Length of car body on center line over end plates, 48 feet.
Length of car body over corner posts, 37 feet 10 inches.
Extreme width of car over window sills, 8 feet $8\frac{3}{16}$ inches.
Width of sliding door opening, 3 feet 8 inches.
Height of car from top rail to top of roof, 12 feet $3\frac{1}{2}$ inches.

The car body is built throughout with structural-steel and pressed-steel shapes, and is designed with continuous structural-steel center sills and plate side girders. The lower members of the side girders form the side sills, and the upper members form the letter boards and deck plates above the windows. The floor and side framing is designed to include cross-bearers which transfer the floor load to the side trusses. Special precaution against the destructive effect of collisions is provided for in the end vestibule framing. The entire car body, exterior and interior, is made fireproof and is thoroughly insulated against extremes of heat and cold, noise, and the effect of vibration. In fact, the structural steel is so arranged that no part is exposed to both the outside and inside of the car except the sashes. The underframe is composed of 6-inch channels and I-beams, which form the side sills and end sills and the center sills, respectively. Another important feature of the underframing included in the design is contained in the body bolsters. These are made of two soft-steel plates with a cast-steel separator in the center. The steel casting, in addition to serving as a separator for the top and bottom plates, is designed to form a housing for the draft springs by extending it beyond the bolsters toward the end of the car body. The center-bearing plates are also of special design and provide for self-lubrication, giving also large contact and wearing areas. The center plates are designed with an oil well surrounding the upper member of the bearing plate which, when filled, permits this member to operate in oil. Each bolster is equipped with a roller side bearing.

The side and end framing of the car body is made up of pressed-steel sections, sheathed on the outside below the windows with 3/32-inch cold-rolled steel plates, which are secured to the posts, belt rail, side sills, and other parts by rivets. The entire interior finish of the car excepting the arm rests on the windows is supplied in a special material—finished mahogany. The floors are of a fireproof, sanitary composition.

At each end of the car are provided vestibules which afford entrance from each side and from the ends. The right-hand corner of each vestibule, on the motor cars, contains a motorman's brake valve, air gauge, master controller, and other necessary apparatus inclosed in a cab formed by a door hinged to swing approximately 120 degrees. This door in one position forms one side of the cab, and in the other it engages with a swinging panel which forms a part of the finished bulkhead.

The body is fitted with six sliding doors, two at each end of the car and two in the center. These doors recede into pockets provided in the car body and are operated with pneumatic apparatus, either from the guard's niche or from the motorman's cab. They are made of pressed steel, suitably insulated, and are $1\frac{1}{4}$ inches in thickness, being equipped with rubber cushions and weather stripping. The vestibules are fitted with doors at the ends to permit an uninterrupted passage from one car to another.

Twelve windows are provided on each side of the car body, the upper sash being fixed and the lower sash arranged to be raised. The sashes are made of bronze and are fitted with brass stops and curtain grooves. Both the upper and lower sashes are glazed with $\frac{3}{16}$-inch plate glass, set in rubber channels. The car body is provided with four longitudinal seats 16 feet $4\frac{3}{4}$ inches in length. These are provided with 2-foot $6\frac{1}{2}$-inch spring backs built into the car body. Both the backs and the seats are upholstered in canvas-lined rattan of small mesh. Twenty-four sanitary hand straps, six on each side of the car ceiling in each end of the car body, are provided for the convenience of standing passengers.

An electric heating system of the forced-ventilation type and provided with a thermostat control will be installed in each car. This system is operated in conjunction with eight exhaust ventilators installed in the roof of the car. Each ventilator is provided with register control, and the six in the car body are connected to two continuous operating mechanisms. All electric wires, both for the heating system and for the lighting circuit, are inclosed in a metal conduit, provided with junction boxes and other necessary fittings to insulate it thoroughly.

Ingenious articulated car in Boston.—Reference has been made in preceding paragraphs to an ingenious new form of articulated car devised in 1912 and put into use by the Boston Elevated Railway Co. for its regular street-car service. This car, which represented the most novel design placed in service in urban traction work during the year, consisted of two of the company's old 20-foot closed cars with one vestibule and platform removed from each, the two units being assembled into a single car 62 feet 10 inches long over bumpers, through the use of an intermediate compartment flexibly connected with the two end sections and serving as a center-entrance prepayment platform. In this car access to the intermediate compartment is had by means of a folding step attached to the outside of the compartment in front of the doors and about 11 inches below them.

The main object sought in the design of the car, aside from its effective utilization of a heavy investment in small rolling-stock units of low carrying capacity, was to obtain a car capable of holding at least as many passengers as the standard semiconvertible cars owned by the company, to produce a piece of rolling stock which could be used on narrow streets and on short curves without dangerous overhang, and at the same time to provide improved facilities for convenience and safety of passengers when entering or leaving. The first car of this type has been in service since early in September, 1912, and has met with complete success, both from the company's point of view and from that of the public. A second car of this general type has lately been placed in commission, and a number of improvements have been effected in its design, the most notable feature being the adoption of the principle of stepless operation. In the new car the floor of the center section, where the doors are located, is arranged with a lower level than in the first car of the type, so that passengers step directly from the street into the intermediate compartment, which is located 14 inches above the roadway. This is an unusually low height of step, and the car may, in fact, be considered stepless in the same sense as the so-called stepless center-entrance cars now operating in Manhattan and Brooklyn Boroughs, New York City.

The general design of the car is similar to that of the first one, but the utilization of the stepless principle made a number of changes necessary in the underframing of the intermediate compartment. After the passenger has stepped into the center compartment and deposited his fare in a fare box in the middle of the compartment, a second step of 10 inches is taken in order to approach the doorway leading into either end section, and the platform reached by this step has a ramp with a rise of 2 inches between its outer edge and the step riser which is surmounted prior to entering the end section. As in the first car, this riser is 5 inches in height. The lowering of the center platform has been accomplished by offsetting the center sills of the central or intermediate compartment, the side sills being supported at the same height as the lower portions of the center sills by channel irons passing through center-sill reinforcing plates and resting on the bottom members of the center sills. A change has also been made in the bolster arrangement, the side-bearing plates resting on top of rollers carried on the top of the bolster support instead of on the end sills of the cars. This permits the use of a flooring about 8 inches wider for the passageway between the intermediate and end sections.

The flexible curtain inclosing the passageway between the intermediate and end sections of the car has been materially improved, and instead of using a continuous diaphragm the bonnets carried by the end sections have been arranged with horizontal hinges permitting vertical movement of the outer ends of the bonnets, which rest in each case on the top of the end wall of the intermediate section. This allows for all necessary movement between the units and at the same time makes a waterproof joint, providing at all times a ceiling line parallel to the floor line of the intermediate compartment and thus enabling the sides to be closed with spring-roller curtains.

One-man prepayment cars.—One of the interesting developments of the period in creating new facilities for street-car travel has been the return of the old type of car exemplified by and famous as the "bobtail," operated by one man who in addition to driving his team was supposed to be able to play conductor as well and see that all the fares were paid, besides making change when called upon to do so. The introduction of electric power soon drove off the streets the bobtail horse car, which had shown ability to stand other competition; but now the success of the modern prepayment car methods has brought "on the map" new types of the one-man car that were not previously practicable. The car has apparently a very distinct place in enabling service to be given in districts and along thoroughfares where heavier cars and more expensive systems of operation could not be supported by existing traffic. Obviously a smaller car can be used, and even old cars obsolete for some other classes of city service can be utilized in the new work. Thus, for example, in 1913 the Detroit United Railway Co. put in operation at Ann Arbor, Mich., a city of 15,000 people, a single-truck car combining the one-man operation with the pay-as-you-enter principle. The change from two-man cars was made to reduce the cost of operation and yet give better service. The type of car had become obsolete in Detroit, but still was relatively new and eminently useful for traffic elsewhere. Only a small expense was involved for overhauling. In making the change it was necessary to arrange the vestibules so that the doors could be opened and closed mechanically by the motorman at one end and locked at the other. The usual door-operating mechanism is used, but the handle can be readily removed for use at the opposite end when the car is turned. Thus entering travel is directed through the front door to the fare box under the eye of the motorman-conductor, and it is practically impossible for a passenger to open the rear door and come in. The removal of the bulkhead, except for a portion as wide as the longitudinal seats, gives the operator a clear view of the car interior, while push buttons enable the passenger to signal for a stop. The fare box is installed in a corner of the vestibule just back of the motorman's car controller on the left side opposite the entrance doors. This arrangement is convenient for fare collection and leaves a clear aisle for passengers when boarding and alighting.

A number of statements from street railway managers as to their opinions and experience in regard to the subject afford probably the best guide as to the status of this practice. A survey of this kind was secured during the early part of 1913, and the data given are of much interest.[1] In this connection Mr. R. B. Stitchter, general manager of the Waco, Tex., Street Railway, may be quoted as follows:

The cars were originally built with a view of one-man operation but so that, when occasions of heavy traffic demanded, they could be operated well with two men. The older types of fare boxes have been in use, and the trainmen are permitted to make change only. We are at this time trying out the later types of fare boxes. The system is so laid out that every car in service passes in front of the company office, the trainmen are supplied with $5 in nickels, and a change man remains on duty during the entire period of operation and keeps the men supplied. Twenty nickels are stacked and held together with a spring clip for the purpose, so change can be quickly and accurately made when required by the trainmen.

The hours of car operation per month will exceed 10,000, and the addition of another trainman per car-hour, at 18 cents, would mean an increase of $1,800 per month. The saving does not amount to this much, however, as at present some of the lines have such heavy traffic that, the cars being of the single-truck type, it has not been found possible to operate with one man and make sufficient headway. There are other lines which during the heavy traffic period are supplied with an extra man to each car to act as motorman, the regular man during such period of heavy traffic confining his duties to acting in the capacity of conductor.

There are 24 cars on the system, all arranged for one-man operation. During November, however, four double-truck motor cars and four double-truck trail cars were received and were greatly praised by the mayor and members of the city commission and others interested in the city's welfare and development. These later cars embody the single-man, pay-as-you-enter feature, with outside closing doors operated by the motorman, are provided with cash fare boxes, and are without bulkheads. The side framing consists of T-irons, extending from the floor framing up one side and down to the floor again on the other side, in one continuous piece. All of the motor cars are equipped for double-ended operation except four. The amount to be expended to convert old-style cars to one-man pay-within cars depends on the number of car-hours, the rate paid the trainmen per hour, and other local conditions which are easily ascertained and secured in each particular case.

We expect trainmen to request payment of fare, cash, ticket, or transfer, the same as in two-man pay-as-you-enter operation. All fares are registered on a double-fare register as cash or tickets. Transfers are issued at certain transfer points. We have not tried a transfer-issuing machine. The trainmen are instructed to announce streets and to assist only elderly persons on or off the cars. Our pay passengers per car-mile average a little in excess of four.

One-man operation gives a little slower schedule than two-man operation. The schedule, however, under proper training and proper inspection, in our experience, is sufficiently rapid to please all patrons, and, in fact, is as rapid as safe conditions of operation will permit, regardless of whether the car is operated by one man or two men.

Our observation shows that a single-man car, provided with lever to operate folding doors and steps, if properly operated, is practically as safe as when operated by two men, and the number of accidents and the amount of damage resulting from one-man operation do not exceed to any perceptible degree those with two-man operation. As previously stated, however, when the traffic gets heavy, in order to make the same schedule, it is necessary to provide two men, and the results, from the accident standpoint, depend largely on the provision by the superintendent of inspectors of two men just at the time when traffic becomes sufficiently heavy to justify it.

The attitude of the public toward the one-man car seems to be very favorable. There is no objection to it whatever except in certain localities where a large proportion of the passengers are negroes, and

[1] Electric Railway Journal, Mar. 29, 1913.

in such cases it sometimes becomes necessary, harkening to public opinion, to segregate the negroes in the rear of the car and permit them to enter and leave through the rear. In the case of one-man-operated cars it is ordinarily required that all passengers enter and leave by the front entrance.

Our experience with the one-man-operated car is that it very often enables the traction company to give street-car service in thinly populated districts where, if two-man-operated cars were required, such service could not profitably be maintained, and with the exception of lines blessed with quite heavy patronage the system of operation can be so laid out that very economical and satisfactory service can be given to the public.

Mr. H. W. Waggener, general superintendent, Atchison (Kans.) Railway, Light & Power Co., says:

The cars we operate are the ordinary semiconvertible single-truck cars with both rear and front platforms. The rear doors are kept closed and no fare boxes are used. We supply $5 in change to the trainmen. We have eight cars, all double-end. We instruct trainmen to exact prepayment of fare in all cases on one-man cars. The fares are registered by hand. Transfers are issued when passengers leave the car at the junctions. The motorman announces streets and assists passengers in boarding and alighting, or with heavy packages, etc., if they need assistance.

The average number of passengers per car-mile on our one-man cars is 4.8. The maximum speed of the one-man cars is 8 miles per hour. The schedule speed is 7 miles per hour. There has been no effect on our schedule speed from the introduction of one-man cars. We have employed a second man when traffic is heavy; he stands inside of the car at the front end and collects and registers the fares. So far as our observation goes the number of accidents has not been increased by one-man operation. We have never had any trouble with passengers, but many of them buy tickets to save trouble in making change when they enter the cars. All objection on the part of our public against one-man cars disappeared in a short time.

The saving in platform expense due to the use of one-man cars is not offset by disadvantages of any kind. We have received advantages from one-man operation in addition to our reduction in platform expense. All fares are apparently registered, and a saving has resulted of $2 per day on each car. This city has between 17,000 and 18,000 inhabitants. We came to the conclusion that one man could collect fares and register them practically as quickly as could be done with a conductor, and it became a question of cutting expenses; hence the adoption of the system.

I certainly recommend one-man operation for companies in small cities and for the outlying lines of companies in large cities, especially where the schedule is not too fast. For a number of years our cars were operated as one-man cars, passengers paying their fare when they left the car, but about two years ago this method was changed to payment as the passengers entered. This last arrangement has been much more satisfactory to the general public. On holidays, such as the Fourth of July and other big days, when the traffic is particularly heavy, it becomes necessary for us to put on a conductor during the congested hours only.

Mr. Attillo Norman, treasurer, Freeport (Ill.) Railway & Light Co., says:

Four of our cars were originally for one-man operation and two were reconstructed. The cars are double-end. Registering fare boxes are used, and very little expense was necessary to remodel our old-style cars for one-man prepayment operation. We instruct trainmen to exact prepayment of fare in all cases on one-man cars. Trainmen register fares by hand and issue transfers in the usual manner. The motorman announces streets or assists passengers in boarding and alighting, or with heavy packages, etc., if they need assistance.

Our average number of passengers per car-mile on one-man cars is about three and one-half. Our schedule speed is 8 miles per hour. Our runs are short, and this includes turning time. There was no effect on our schedule speed from the introduction of one-man cars. We have never employed a second man on our one-man cars. So far as our observation goes, the number of accidents has been decreased by one-man operation. Our car-mileage is greater with the one-man cars than with the two-man cars operated previously. Our traffic has increased, but we are not sure that this was not due to other causes.

The attitude of the public toward one-man cars at the beginning of operation was that it was willing to have us try them out. Sentiment seems favorable now. The saving in platform expense due to the use of one-man cars is not offset by disadvantages of any kind. We have received advantages from one-man operation in increased receipts and fewer accidents. We introduced one-man operation for the purpose of economy in operation and because we expected increased receipts and fewer accidents. We recommend one-man operation for companies in small cities and for outlying lines of companies in large cities.

Mr. Samuel Barnes, general manager, Cape Girardeau-Jackson (Mo.) Interurban Railway, says:

We have operated our one-man pay-as-you-enter cars for a little more than two years. We were about the first company to operate one-man cars. During this time we have had but one accident. We feel that this is due mostly to the fact that the motorman is placed in a position where he realizes that he is wholly responsible for the car operation and is not depending on the efforts of any one else to avoid possible accident. Furthermore, we have some 7 per cent grades running straight toward and within one block of the Mississippi River banks or levee. When going down this grade, if the car gets beyond the motorman's control, it is necessary for the motorman to throw off the overhead switch and reverse the controller seven or nine points to allow the motors to generate sufficient current to hold the car to a controlling point of speed. Previous to the one-man operation this effort to avoid a runaway with the car on the down grades depended on the conductor to some extent, and at such times he was liable to be inside of the car collecting fares; but under the new system the motorman has quicker access to the means of remedy. There are other instances wherein the one-man pay-as-you-enter car is far superior to two-man car operation.

We reconstructed our cars ourselves. Each man has to furnish his own change, $10. There are six one-man cars on the system, or 10 cars of all types. One-half of the cars are single-end and the remainder are double-end. The expenditure that a company would be justified in making to remodel old-style cars for one-man prepayment operation depends on the type of car and general traffic conditions. Our single-end cars cost $240 per car and our double-end cars $480 per car to reconstruct. We instruct trainmen to exact prepayment of fares in all cases on one-man cars. Fares are registered by hand, and regular transfers are issued. The motorman announces streets and assists passengers in boarding and alighting, or with heavy packages, etc., if they need assistance.

The schedule speed on our one-man cars is 9½ miles per hour. We are making just as good schedule time as with the old system. We have never employed a second man on one-man cars. The number of accidents has been decreased by one-man operation. Our car-mileage is greater with the one-man cars than with the two-man cars operated previously. The traffic was affected by the establishment of one-man cars on the start for about 10 days. The change seemed to cause a little inconvenience to the public, but after that everything worked smoothly. Some people were not favorable to the idea of putting change in the box, but this attitude has changed. All the results of one-man car operation are advantageous. We introduced the cars to reduce the cost of operation and improve the receipts, and by all means recommend one-man operation for companies in small cities and for outlying lines of companies in large cities. During big days our one-man cars carry 1,800 to 2,000 passengers per day each. We have had days in which these cars have handled 900 passengers each in three hours.

Mr. J. T. Skinner, manager, Lawrence (Kans.) Railway & Light Co., says:

In preparing cars for one-man operation we simply closed up the rear door and folded up the rear step and put a fare box on the front end of the car. Fare boxes are used. We loan the trainmen for change $10. The one-man-operated cars save approximately 40 per cent of platform labor. We operate regularly 7 one-man cars on the system, but have a total of 11 double-end and 3 single-end cars.

A company is justified in folding up the rear step, closing the rear door, putting the fare box or register on the front end of the car, and going ahead without any further changes except to adopt the near-side stop. We instruct trainmen to exact prepayment of fares in all cases on one-man cars, except where the trainmen know that the person will hunt out the fare and drop it in the box before leaving the car. Old people and women with children and bundles will frequently take a seat near the front end of the car, hunt out the fare, and drop it in the box after the car has started.

Trainmen ring up fares by hand as they are dropped in the box. If the car has a clear running space, the trainman punches his transfers with the car in motion. If not, the transfers are punched and handed to passengers as they leave the car. Only about 10 per cent of the passengers require transfers. Trainmen announce transfer points and streets for strangers. Our average number of passengers per car-mile on one-man cars is about four. Our maximum speed on one-man cars is 20 miles per hour, and our schedule speed approximately 8 miles per hour. Since the introduction of one-man cars, we have used a somewhat slower schedule. When we have large crowds to handle, we open up the rear door and use two men, collecting fares at each end as passengers board cars. This allows a car to be loaded and unloaded quickly. The number of accidents has been decreased by one-man operation. We have not found that certain classes of passengers are more likely to cause disturbance on one-man cars than on a car with two trainmen.

Our car-mileage has been decreased somewhat with the one-man cars on account of the slower schedule. There has been no change in traffic due to one-man cars. The public thought it was a sensible thing to introduce one-man cars on a small road rather than to cut down car service to effect economies. The saving in platform expense due to the use of one-man cars is not offset by disadvantages of any kind. There are advantages in one-man operation in addition to the reduction in platform expense. One man kept busy will render more efficient service than two men partly idle. We introduced one-man operation because there is no need of two men on a small road except during a few days out of a year. I recommend one-man operation for companies in small cities; and for outlying lines of companies in large cities, where the regular riding is light, one man is better than two.

Mr. L. W. Hess, general superintendent, Northern Illinois Light & Traction Co., states as follows:

Our one-man-operated cars are ordinary cars. We close the back doors and make all people get on the front end. In summer we have both front doors open, and in winter the right-hand front door in the direction the car is going. We supply $4 to the trainmen for change. In September, 1912, our revenues per car-mile on one-man-operated cars were $0.1897 and our expenses were $0.0918. We have six cars, and all are operated by one man except on large-traffic days. All the cars are double-end. The amount which a company would be justified in spending to remodel old-style cars for one-man prepayment operation would depend on local conditions.

The trainman records the fares on a fare register. He collects as the passenger gets off and the car is at stop or when he comes to a switch where cars pass. He steps inside at this point and collects fares. Transfers are issued by the motorman, who does not announce streets except when the passenger asks to get off at a certain place. The motorman is required to help all passengers who need it. Our average number of pay passengers per car-mile on one-man cars is 3.93. Our schedule speed is 12 miles per hour under the ordinance. One-man cars run a little faster under certain local conditions than was the practice before. On large days we have employed a second man on our one-man cars. He acts as conductor.

According to our experience, the number of accidents has not been increased by one-man operation. We have never had an accident to a passenger getting on or off a one-man car. I do not think collisions are increased, as the man on the front end is the man to look out for that, anyway. I do not think disturbances are more apt to occur on one-man cars than on a car with two trainmen. Any person who wants to start trouble is usually under the influence of liquor, and the number of the crew would make no difference. Our car-mileage is not greater with the one-man cars than with the two-man cars operated previously. The traffic was decreased slightly at the beginning by the introduction of one-man cars. There was some opposition toward them at first, but this attitude has changed. I think the saving in platform expense due to the use of one-man cars is not offset by disadvantages of any kind.

There are reductions in one-man operation in addition to the reduction in platform expense. The responsibility of operation can not be shifted to the other man, and there are fewer men to bear the responsibility. We introduced one-man operation to economize in expenses, as we can not afford two men on a car. I recommend one-man operation for companies in small cities and for outlying lines of companies in large cities if they want to save money. We have operated our line almost fifteen years and have never had a suit entered in court because of a street-car accident, although, of course, we have had a number of accidents.

Mr. E. E. Downs, general manager of the Belvidere (Ill.) City Railway, says:

The cars on the Belvidere city line were built originally for one-man operation. A remodeled fare box is used. It rests on a pedestal on the platform convenient to the passengers and the motorman. The motorman supplies himself with $10 in change, but 75 per cent of the passengers have the exact fare ready. We operate two double-end one-man cars. We instruct trainmen to exact prepayment of fares in all cases on one-man cars. Fares are recorded by a hand-register cord hanging directly in front of the motorman. Transfers are not issued. The motorman announces streets or assists passengers in boarding and alighting, or with heavy packages, etc., if they need assistance. Our maximum speed on one-man cars is 15 miles per hour. The schedule speed is 7.5 miles per hour. A second man is hardly necessary, except on special occasions, to make change and expedite loading and unloading. At such times he stands in any place not occupied by passengers. One-man operation obviates all loading and unloading accidents, but certain classes of passengers are more likely to cause disturbance on one-man cars than on a car with two trainmen.

At the beginning of operation everybody seemed pleased and took to the new order of things very kindly. The saving in platform expense due to the use of one-man cars is not offset by disadvantages of any kind. I recommend one-man operation for companies in cities of even as high as 40,000 population.

Unusual subway cars for Greater New York.—The New York Municipal Railway Corporation, a subsidiary of the Brooklyn Rapid Transit Co., filed with the public-service commission of New York City in August, 1913, its design for an unusual new type of car intended for subway use, and also exhibited publicly this new car at its car shops. There are no entrance doors at the ends, but each car has three double doors on each side, although it is proposed to operate only the center pair during hours of light travel. All the doors are pneumatically controlled by the guard, who is elevated on a pedestal alongside the idle pair of center doors, from which position he is able to see all passenger movement with ease. End doors are also provided for going from car to car. The seating plan is such that permanent and temporary longitudinal seats are provided near and in front of the doors, while one row of transverse seats is placed midway between the two pairs of side doors. These transverse seats are of the back-to-back design, one bench being wide enough for three passengers and the other for two. With all doors on one side in use, the car will seat 78, but when operation is limited to the center doors it will seat 98 passengers. All cars are motor cars, in view of their great capacity and length, namely, 67 feet. The outside color of the cars is dark green; the interior is light enamel. Mechanical ventilators are used.

The following comparisons are made by the New York Municipal Railway between this car and that now used in the subway service of the Interborough Rapid Transit Co.:

	New York Municipal Railway car.	Interborough Rapid Transit subway car.
Length	67 feet	51 feet 5 inches.
Width	10 feet	8 feet $8\frac{3}{4}$ inches.
Seats:		
In rush hours	78 persons	44 persons.
In nonrush hours	98 persons	46 persons.
Average walk per passenger from seat to door	$82\frac{1}{2}$ inches	90 inches.
Length of train (eight cars)	538 feet 4 inches	513 feet 5 inches.
Total space in train available for passengers	4,711 square feet	3,702 square feet.

The company estimates that with a train load of 1,200 persons, that now carried in the present 10-car subway trains during rush hours, eight cars only of the new type would be required. With 150 passengers per car 78 would be seated and 72 standing. As there is 370 square feet of standing space per car, each standing passenger would have an average of 5 square feet.

Improved California-type cars.—During 1913 the United Railroads of San Francisco placed in service 65 new cars of the California type, which in general embodies the idea of having open sections of the car at each end with a closed section in the middle. The principal dimensions are as follows: Length over bumpers, 47 feet; length over corner posts, 32 feet 4 inches; outside length of closed section, 15 feet $4\frac{1}{2}$ inches; width over drip rails, 9 feet 2 inches; height of roof above rail, 11 feet $3\frac{5}{16}$ inches; truck centers, 20 feet $10\frac{1}{4}$ inches; truck wheel base, 4 feet 6 inches. The entire side plate is designed to act as a plate girder, using the side sills as the bottom chord and the $\frac{3}{32}$-inch side plate as the web plate, with intermediate stiffener angles at each side post. The upper chord is composed of angle iron, cut out at each side post, in addition to which there is an over-truss rod of flat bar steel to take a portion of the platform load. This method of side-plate construction does not in any way depend on the side post for strength, thereby allowing the use of a very light side post, which gives the car a light appearance above the window sills.

The floor area of each platform, 46.25 square feet, is larger than that of any other car previously in use in San Francisco and is of great advantage in loading and unloading. On observation the company has found that 25 persons can stand on the rear platform, which is a great help during rush-hour loading at congested points. Stop-watch tests have shown the average loading time per passenger to be 1.1 seconds, and for unloading by front exit only, 0.95 second per passenger. Great consideration was given to step and platform design, which is the heart of the prepayment type of car. The distance to the first step from the street is $15\frac{1}{8}$ inches, from the first step to the platform $12\frac{1}{8}$ inches, and from the platform to the car proper, with the use of a 2-inch platform ramp, 10 inches. This arrangement places the floor of the car only $39\frac{1}{4}$ inches above the head of the rail.

The conductor's railing, which can be locked up to the ceiling, is designed to give the maximum-width entrance. It also acts as a motorman's guard-rail and serves to operate the folding step on the blind side of the car, thus making it impossible for the car crew to neglect to raise or lower the step at the proper time.

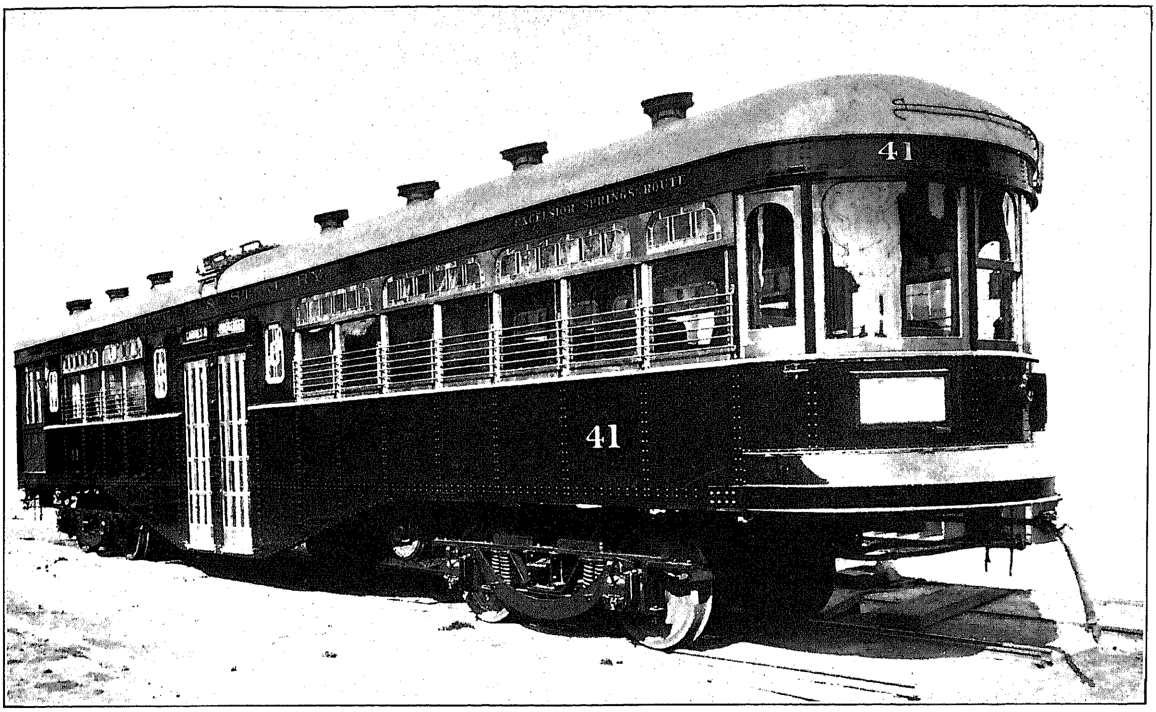
The car has four folding platform seats which are used only on the front end of the car. These seats afford an extra seating capacity for six persons, but interfere in no way with passengers who leave the car by way of the front exit. Wired, polished plate glass, $\frac{3}{8}$ inch thick, is set in each side sash of the platform windows to protect users of these very popular seats in case of a slight collision.

All the operating mechanism of the sliding exit gates is concealed behind the panel back for folding the platform seats, which is removable. The mechanism has been so arranged that the momentum of the car does most of the work in opening and closing.

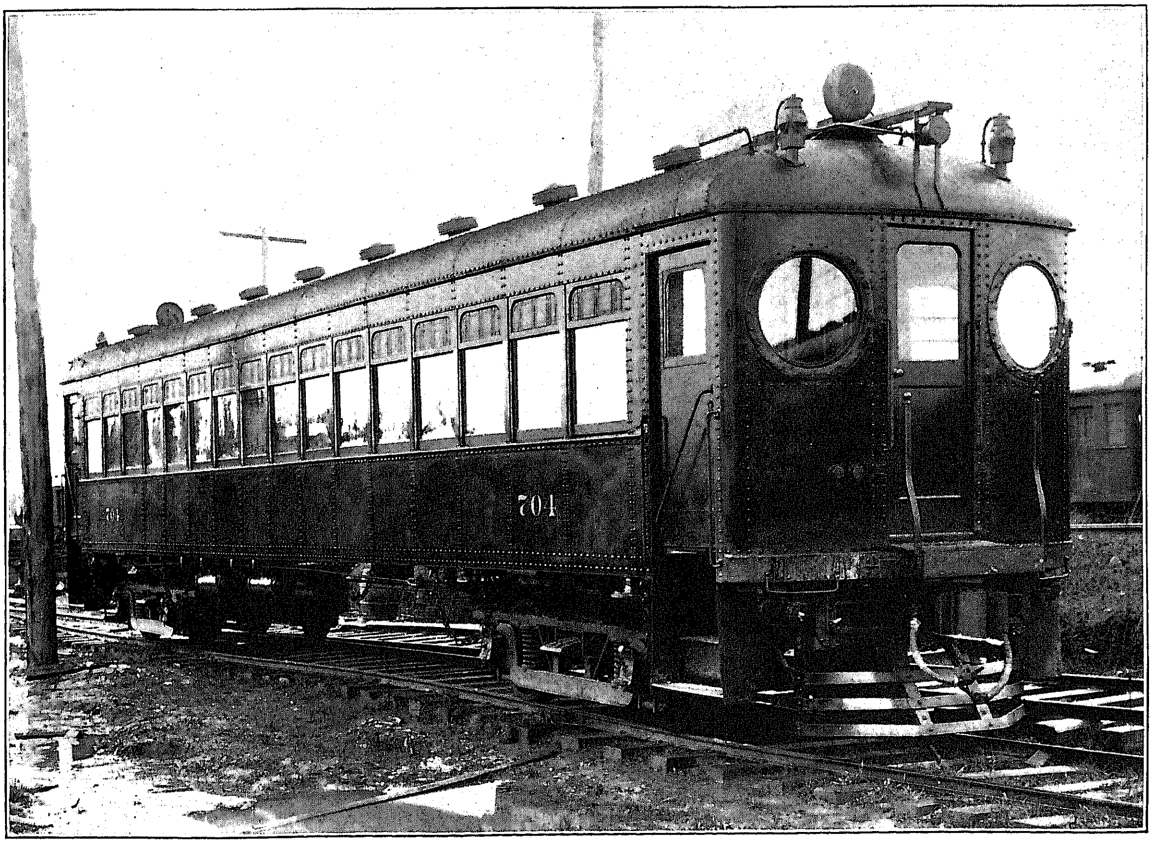
Ventilation for the closed section is obtained through four roof funnels, two acting as intakes and two as outlets. In addition, a perforated panel ventilator is carried at each end of the closed section over the window opposite the door.

Two different seating arrangements are used, varying only in the closed section, where in some of the cars cross seats are used on one side instead of longitudinal seats on both sides. In the cars that have longitudinal seats on both sides of the closed section there is an unobstructed space under the entire length of seats, thus permitting the free use of a vacuum cleaner.

The seats in the open sections are of special design, being pivoted only and not throw-over. They are of slat construction, with natural finish to match the interior finish of the car. These special seats permit a clear aisle space of $31\frac{1}{8}$ inches between the cross seats. After careful study and actual tests



ALL-STEEL, CENTER-ENTRANCE, INTERURBAN CAR, KANSAS CITY, MO.



ALL-STEEL, INTERURBAN CAR, PORTLAND, OREG.

(Face p. 368.)

LOW END-ENTRANCE CAR FOR CITY SERVICE, BROOKLYN, N. Y.

TYPICAL CENTER-ENTRANCE TRAIL CAR, CLEVELAND, OHIO.

the company decided to use vertical hand rods in the closed section in place of hand straps. Passengers of various heights, of course, can use these rods with equal comfort. The stanchions and screens at the end sills serve two purposes: First, they define clearly the dividing line between the platform and the car proper, so that the conductor can ask passengers to step into the car; second, the screens act as a guard to prevent passengers who are occupying seats in the open section from putting their feet against passengers who are occupying the folding platform seats. As all stanchions are enameled white, they are easily kept clean.

The seating capacity, including that of the folding platform seats, is 50 for the cars with longitudinal seats on both sides of the closed section and 52 for those having cross seats on one side of the closed section.

Trackless trolley bus.—A trackless trolley bus was put in operation in Merrill, Wis., in 1913, by the Merrill Railway and Lighting Co. The bus seats 18 passengers and is equipped with a 500-volt, 15-horsepower series motor. A five-step railway-type controller and standard resistances are used. The car is of the one-man, pay-as-you-enter type and operates over a route of about 1 mile, connecting at one end with the regular street railway cars of the company. The company plans to extend the bus system to other parts of the city, and also to build one or two suburban extensions. The trackless trolley system was used instead of the ordinary cars on rails, for several reasons. One was that in the mile of route the line crossed three steam railroad tracks and passed over one long bridge. With a street railway franchise, the company would have been obliged to keep the bridge in repair, as well as the roadway between the tracks and for 1 foot outside. This expense was saved, as well as the expense of installing and maintaining three steam railroad crossings. Altogether the company estimates that it made a saving of $70,000 in track, exclusive of repairs and depreciation, and that it is also saving about $400 a year in power. The bus does not hold as many passengers as an electric car, but has ample capacity for the traffic.

The single motor drives the two rear wheels by means of a longitudinal shaft, connected by bevel gears to a jack shaft with differential gear, which in turn is connected with the rear wheels by chains, the method of connection being very similar to that employed in an ordinary automobile truck. Solid rubber tires are used. Connection is made to the two overhead trolley wires by means of two separate trolley poles with swiveled harps and bases. The poles are extra long to give a lateral freedom of movement of 10 feet to 12 feet on both sides of the trolley wire. This prevents interference with the bus from other street traffic. The two trolley wires used by the bus are fed from the two trolley wires of the local railway system, which is equipped with a complete metallic circuit.

The operating expenses per car-mile are estimated as follows: Management, salaries, and wages, 3.2 cents; electric power, 4.85 cents per watt hour, or 1.6 cents; tire renewals, 3.4 cents; maintenance, 1.8 cents; total, 10 cents. The main dimensions of the bus are: Length over all, 18 feet 6 inches; width, 6 feet; height in passenger compartment, 6 feet 8 inches. The weight empty is about 3 tons.

Express and interurban cars.—Various new departures and experiments in both classes have been made, altogether too numerous to specify. It must suffice to select one or two examples. The Northwestern Pennsylvania Railway, for instance, has developed and put in use a combination parlor car, smoker, and baggage coach, operated in a train for "limited" service between Erie and Meadville, Pa. The arrangement is unusual in that the two cars operate with the passenger entrance in the center of the train only. The combination car is placed at the front end of the train. Each car is 50 feet 10¼ inches long over the buffers, 49 feet 6¼ inches long over the vestibules, 39 feet 6¾ inches long over the end plates, 9 feet 4 inches high from sill to top of roof, 8 feet 6 inches wide over all, and 8 feet 2 inches wide over the sills. The distance between the center lines of the bolsters is 27 feet 9 inches, and the wheel base of the trucks is 6 feet 6 inches.

While a center-entrance train is not altogether new, there is novelty in the car plans. The baggage and express section of the combination car is furnished with a sliding door of 4-foot opening on each side and with folding slat seats. The motorman's cab, which is placed at the right-hand side, is provided with a 20¾-inch inside swing door and a 31-inch swing door to cover the front entrance to the car. A space between the smoker's compartment and the baggage compartment is reserved for the heater, the toilet room, and lockers for the crew, card tables, etc. The passengers' platform at the rear is provided with a 31-inch swing door on each side.

The second car of the train has a front platform which is similar to the rear platform of the combination car. The rest of the car, however, is divided by partitions with center doors into a section with cross seats designated as the ladies' compartment, a section with individual chairs called the parlor compartment, and finally a smokers' section de luxe at the rear. The seats in this smaller smoking compartment are removable, so that the platform may be used for operation if desired. All seats are upholstered in crimson plush. An extra fare is charged for the use of the parlor compartment and the smoking section which adjoins it.

As to freight or express cars, attention may be drawn to those put in operation in 1913 by the Bay State

Street Railway of Boston, Mass., for use on the through lines of the company between its Boston freight and express terminals and points in southern Massachusetts and Rhode Island. The new cars represent a striking advance in rolling stock built for this class of service, and are said to be the lightest-weight express cars of their capacity thus far developed. These cars are of the double-truck, flush-platform type, with side and end doors, steel underframing, and semisteel body. The general dimensions are as follows:

Total length over bumpers, 39 feet.
Length between screen bulkhead partitions, 30 feet.
Width over side plate, 8 feet.
Total width over all, 8 feet 2 inches.
Height from rail to top of floor, 46 inches.
Height from rail to top of trolley board, 11 feet 9 inches.
Distance between truck centers, 22 feet.
Wheel base of trucks, 6 feet 4 inches.
Wheel diameters, 34 inches.

The carrying capacity is 20 tons, and the total weight of the car equipped, but without load, is 45,800 pounds. This represents a saving of more than 4,000 pounds in weight in comparison with the earlier express cars used by the road.

New funeral trolley cars.—Cars of this type have been previously described, and there are several in operation. The Philadelphia Rapid Transit Co. placed in commission in 1912 a special funeral car, which may be chartered for transporting funeral parties to any of the many cemeteries reached by the company's lines. The car is named "Hillside," after one of the cemeteries in the suburbs of Philadelphia on the Glenside line. It seats 40 persons in the main compartment and 6 persons in the pallbearers' compartment. A few additional seats are provided by the use of camp stools. The coffin is carried in an inclosed cabinet or vault occupying a portion of the pallbearers' compartment. The coffin is placed in this vault from the outside by lowering a section of the panel in the side of the car, which is hinged at the lower edge for this purpose. To the inside of the two upper corners of the hinged panel are attached chains which pull against automatic equalizers such as are used for operating Pullman berths. This counterbalancing device facilitates the raising and lowering of the panel and also serves to hold the panel in the open position. When the coffin is to be placed within the cabinet, the hinged panel is swung downward to a horizontal position, where the chains hold it at right angles to the side of the car. On the floor of the cabinet is a movable platform mounted on rollers, which is drawn out from the cabinet on to the shelf formed by the lowered panel. The coffin is then placed on this platform, and the platform and coffin are pushed back within the cabinet without jar or friction. When the panel is raised into place, the coffin is concealed from view. The panel is securely fastened by means of two locks operated by handles on the outside. The top of the coffin cabinet is about 3 feet above the floor in the pallbearers' compartment and forms a suitable place for displaying floral emblems.

For convenience in conveying the coffin from the residence or church to the car, a small, rubber-tired, collapsible truck is provided, which makes it possible to move the coffin over the sidewalk or street with no inconvenience or undue effort on the part of the pallbearers. The truck is folded into a small case and is carried on the car, it being also used at the cemetery for transferring the coffin from the car to the grave. By the use of this truck it is entirely feasible to move the coffin a block or two in order to reach the car line.

The car is appropriately finished and decorated. The exterior is in green, with lettering and striping in gold. The interior is in mahogany, with the ceiling in a lighter green decorated in gold leaf. The windows are draped with heavy black velours. The seats are finished in black Spanish leather. All metal trimmings are oxidized. The effect as a whole is one of dignified beauty and impressiveness, thoroughly in keeping with the use for which the car is intended.

To insure thorough sanitary conditions, the car is cleaned and fumigated after every trip. An iced-water tank is located in the pallbearers' compartment, and the company provides iced water and free sanitary drinking cups.

The car has rolled-steel driving wheels and cast-iron pony wheels. The car body is equipped with two 60-horsepower motors. The weight complete is about 39,000 pounds.

General car outlook in 1912.—While the census reports present in general the aggregate figures which represent the development of the industry at the end of any given period, it is interesting to learn the statistics and data for any given year. Figures compiled by the Electric Railway Journal for 1912 thus indicate that the total number of all new cars ordered in 1912 in the United States and Canada was 6,001, an increase of 1,986, or 49.4 per cent, over 1911. Every effort was made to secure returns, and those from car builders were checked up against those from railway companies; but a few companies did not reply in time to permit the inclusion of their data. The number of cars ordered, classified according to the service in which they are used, is given below:

	1912	1911	1910	1909	1908
Total	6,001	4,015	5,381	4,957	3,111
Passenger cars, city	4,531	2,884	3,571	2,537	2,208
Passenger cars, interurban	783	626	990	1,245	727
Freight and miscellaneous cars	687	505	820	1,175	176

A great many city cars ordered during 1912 were of the prepayment type. A special enumeration is not made of the prepayment cars, because this type is now almost universal in new city cars.

Interurban passenger cars showed an increase of 25.1 per cent over the totals of 1911. The figures for interurban cars include orders for subway and elevated equipment.

Among the striking features of rolling-stock orders in the year was the increase in the use of the near side car. Of this type the Philadelphia Rapid Transit Co. ordered 950 cars; the International Railway, Buffalo, 316 cars; and the Chicago City Railway, 125 cars. The one-man near-side car was also developed. Cars of this type were ordered by the International Railway, the Illinois Traction System, and the Fort Wayne & Northern Indiana Traction Co. Another striking development in rolling stock was the introduction of the center-entrance car. Large orders of this type included one from Brooklyn for 100 cars, one from New York City for 175 cars, and one from Los Angeles for 36 cars.

In addition to the rolling stock listed, there were large sales of gasoline-motor, gasoline-electric, and storage-battery cars for branch lines and suburban service on steam railroads. The facts relating to these will now be presented as a subdivision of the general subject of cars.

Advances in self-propelled cars.

Storage-battery cars.—These cars have come into notable use again, and various types have been adopted during the last few years in different cities and for various classes of service. Batteries of the steel-nickel or lead-lead "plates" are employed, and the cars themselves exhibit a great variety of style and feature.

Three cars of the La Jolla line of the Los Angeles & San Diego Beach Railway are 40 feet long over all, 29 feet 6 inches over the corner posts, and owing to the extraordinary width of 10 feet 4 inches, every one of the 24 cross seats is wide enough for three passengers. The motorman's cabs, in diagonally opposite corners, are separated by a bulkhead and door from the passenger compartment. The operating equipment consists of 202 steel-nickel cells, 10 lighting and control cells, 4 200-volt, 75-ampere motors operated at 700 revolutions per minute, multiple-unit control, and straight and automatic air brakes. The trucks are of M. C. B. pattern, and M. C. B. couplers are used. The combination passenger and baggage car of the St. Joseph Valley Traction Co., Elkhart, Ind., is 52 feet over all, 9 feet 4 inches wide, and is mounted on two M. C. B. trucks of 6-foot wheel base. The main and smoking compartments have plush-covered reversible seats, while the baggage compartment has folding benches. The electrical equipment comprises 225 steel-nickel cells for traction, five like cells for lighting, four motors of the type and capacity used on the La Jolla cars, air brakes, and series-parallel control. An earlier car of this type, furnished with 220 cells for traction and 7 like cells for lighting, has been furnished to the Lorain, Ashland & Southern Railway for service between Lorain and Ashland, Ohio, the road having formerly used gasoline cars. A third combination car, fitted with 225 and 5 traction and lighting cells, respectively, has also been ordered.

The Panama Tramways Co. has ordered 15 cars equipped with both storage batteries and overhead trolley. Among the notable features of these cars are the use of a truck with 7-foot 6-inch wheel base, and operation as prepayment cars. The cars are 20 feet 6 inches long over the posts, 30 feet 2 inches long over all, and 8 feet wide over all. The single-arch roof used is fitted with four ventilators. The car seats 32 in 14 cross seats and 4 corner seats. The cross seats are 33 inches wide, with a 22-inch aisle between them. The electrical equipment per car comprises four motors and two controllers.

The Lewisburg, Milton & Watsontown Passenger Railway Co. has been operating with storage batteries of the lead-lead type since the summer of 1911 over approximately 11 miles of track on the Lewisburg and Tyrone Branch of the Pennsylvania Railroad between Montandon and Mifflinburg, Pa. This company first acquired trackage rights from the Pennsylvania Railroad from Montandon to Lewisburg, Pa., a distance of approximately 1½ miles, including a bridge across the Susquehanna River, in order to connect Lewisburg by trolley cars with Milton and Watsontown. There being a demand for additional local service between Lewisburg and Mifflinburg, which, while very material, did not justify the operation of steam trains by the Pennsylvania Railroad or the expenditure of the necessary capital to install overhead trolley wires, the company was able to extend its trackage agreement with the Pennsylvania Railroad to cover the distance of approximately 9 miles between those places, and to place in service a storage-battery car, which is operated between steam trains on a schedule published in the Pennsylvania Railroad time-table. Movements of the storage-battery car are subject to orders from controlling signalmen of the Pennsylvania Railroad. The car makes five round trips between Montandon and Mifflinburg and three round trips between Montandon and Lewisburg, a total of about 122 miles per day.

A storage-battery car of unusually large size was put in operation at the close of 1912 in the service of handling local passenger and express traffic on a branch of the Chicago Great Western Railway which had been previously operated by steam locomotives. On account of the requirements of the service for which the car is intended, the body has been divided into three compartments, of which one is for baggage and express, another for smokers, and the third, or largest, is arranged like a standard passenger coach.

This car is 49 feet 8½ inches long over drawbar, 9 feet 1 inch wide over drip rail, and 12 feet 6 inches from rail to top of ventilators. It is equipped with 220 nickel-steel alkaline cells for power and ten cells for light. These batteries are placed under the car in two compartments, strongly reinforced with structural shapes and riveted to the underframe. They are of special railway type, having 3 inches of water over the plates. The car is equipped with four 20-horsepower, 75-ampere, 200-volt, series-wound motors, with a speed of 720 revolutions per minute. Two of these are placed on each truck, one on each axle. The axles are stationary and one wheel on each axle is driven by a gear fastened to the inside of the hub, the ratio of reduction being 3.5:1. There are two series-parallel controllers, one on each end of the car, with four series and three parallel positions. All power wires are carried in conduit securely fastened to the underframe. The car is equipped with M. C. B. couplers of standard height of drawbar, locomotive type of pilot on each end, a locomotive bell, and an electric horn. The equipment includes a straight-air system of air brakes with a compressor which automatically cuts in when the pressure drops to 45 pounds and cuts out when the pressure reaches 60 pounds. Hand brakes are also furnished at both ends of the car.

The underframe is made up entirely of structural shapes, riveted together and strengthened with truss rods on each side. The interior finish is of ash and polished bronze in the passenger compartment, which is 22 feet long. This has 10 cross reversible seats, seating two passengers each, two stationary cross seats for two passengers each, and two longitudinal seats with space for one and three passengers, respectively. The seats are covered with woven rattan, and have the usual bronze grab handles. In this compartment is a toilet room with a dry closet and a water cooler. The smoking compartment is 5 feet 3 inches long, and has four stationary cross seats for two passengers each, the total seating capacity of the car being 36 passengers. The baggage and express compartment is 15 feet 6 inches long, with sliding doors on each side. A hot-water heater is placed in it and from the heater pipes run through the other compartments.

The trucks are of diamond-frame type, and while of light construction are exceptionally strong. The wheels are chilled iron, and they are free to rotate independently of each other on the stationary axles. This is accomplished by pressing on to each end of the axle a nickel-steel hardened sleeve over which two trains of rollers rotate. The rollers in turn are held in a nickel-steel hardened raceway pressed into the wide hub of the wheel.

A maximum speed of 35.6 miles per hour on level track and 29.6 miles per hour on a 2 per cent grade has been attained with an energy consumption reported at 30.4 watt hours per ton-mile in the former case and 46.3 watt hours per ton-mile in the latter. The car, including the battery, weighs 29.5 tons, and its train resistance is stated to be 15.2 pounds per ton and 24.7 pounds per ton, respectively, for the level and for the 2 per cent grade. While the radius of action of the car on the rated capacity of the batteries is 79 miles, the actual radius has been found to be 89 miles, and on an overcharge the maximum output of the batteries will permit the car to be operated for 100 miles.

A further development of the storage-battery car has been its use on the New York Railways of New York City in the stepless form, with a single truck. These cars were introduced at the end of 1912, and have a wheel arrangement similar to that of a single-truck car. No truck is used, however, the body being spring-supported directly on the journal boxes. The use of only two axles with small wheels has enabled the designers to bring the points of support near together and by means of a novel motor drive has permitted the body to be carried practically above the axles instead of hanging between them as in the original double-truck stepless car. However, the feature of a single 10-inch step from the street to the car floor has been retained, as well as the fare-collecting arrangement in which the conductor is stationed behind a change desk opposite the entrance door.

The exterior features include a single-arch roof, with upward sweep of the eaves at the ends of the car, permitting front windows of a greater height than at the sides. There are low-entrance doors at the sides of the car, but the lower side panel below a heavy belt rail is concave for wagon-hub clearance on account of the narrow streets in which the car is operated.

The interior has, in general, a longitudinal seating arrangement. There are, however, two stationary cross seats, one in each half of the car, on opposite sides, so that they are almost diagonally across the car from each other. Under these stationary cross seats are located the motors. Owing to the ramp which rises from the low center portion of the car at the doors toward the higher end floors, the longitudinal seats near the ends are at a higher elevation than those near the center in order to give seats with level tops without too great a height above the car flooring. Under the longitudinal seats are the storage batteries, the entire space thus afforded being used for this purpose except short sections in which are located the heaters and motorman's space. Based on a 17-inch allowance for each passenger, the seating capacity of the car is 34. All of the seats are covered with rattan, and in general are 16½ inches wide at the hip line.

Separate compartments are not provided for the motorman, and the entire rear end of the car is in consequence available for seated passengers, the controller being covered when not in use by a swinging section of the seat back near the center portion of each end of the car. At the operating end a removable section of the seat is drawn out of place, turned around, and reinserted in the horizontal slides in which it moves, thus forming a seat with a back for the motorman. When turned around in this manner the seat is pushed in only part way, so that room is provided for the motorman's knees sufficient to allow him to operate the foot brake. The brake is of the automobile type with pedals at the extreme ends of the car, which are consequently concealed by the seats when these are in the position for use by passengers. The arrangement eliminates the necessity for a bulky brake wheel or ratchet handle likely to interfere with the convenience of passengers or reduce valuable seating space. Roller curtains are provided at the motorman's sides and back in order to protect him against the glare from the interior when the car is lighted at night and to isolate him from the passengers. These curtains are carried on rollers attached to the ceiling and roll up out of the way when not in use. They are guided by enameled stanchions.

The main-entrance doors are of the folding type. Owing to the small seating capacity the door width is only 25 inches, this being considered ample for the service in which the car is used. This gives room for only a single file of passengers, but it provides extra seating capacity and also permits the use of a single folding door which can be operated manually by the conductor, thus eliminating the weight of an operating mechanism as well as the necessity for compressed air, which on this car is not needed for the brakes. The operating mechanism is a simple bell crank attached to the door and connected under the floor by a rod to an operating crank at the opposite side of the car from the entrance. This position of the operating crank permits the conductor to be located in the same position in which he is in the original stepless car and yet enables him to operate the door without moving from his position. The car body is built up on a structural-steel underframe, to the side sills of which is riveted steel-plate side sheathing extending as high as the belt rail for the entire length of the car.

The general dimensions and weights are as follows:

Length over all, 28 feet 9 inches.
Height over all, 8 feet 8 inches.
Width at sills, 6 feet 7 inches.
Greatest width at belt rails, 7 feet 9½ inches.
Wheel base of single truck, 7 feet 6 inches.
Slope of ramp in floor, 6 inches in 8 feet 6 inches.
Diameter of wheels, 21 inches.
Height of step from street, 10 inches.
Seating capacity, 34 17-inch seats.
Weight of car complete, 16,500 pounds.
Weight of battery, 4,300 pounds.
Weight of car without battery, 12,200 pounds.

The weight of the car, including the battery as it stands, is 485 pounds per seated passenger, or for the car alone without the battery only 360 pounds per seated passenger.

The drive is unquestionably one of the most interesting of all of the original features of this car. The two motors are located under the two transverse seats diagonally opposite to each other. Each motor rests on the bottom framing over a space formed by a longitudinal I-beam along the center line of the car, two of the needle beams, and the side sill. Below the motor is a back gear shaft supported in bearings attached to the underside of the framing. On this back gear shaft, which is driven by a gear meshing with the motor pinion, is a sprocket wheel from which a slow-speed roller chain drives another sprocket on the car axle, the latter sprocket being located just outside of the wheel. The wheels are 2 feet 3½ inches nearer to the center line of the car than the motors, and the chain drive is practically horizontal, thus permitting vertical motion of the wheel between the pedestals independently of the motor supported on the car body. The wheels are pressed on to the axles and in consequence those on either axle can not revolve independently of each other. The drive provides for 100 per cent of the weight upon the traction wheels.

The two motors are of double-reduction gear, rated at 85 volts and 40 amperes, with a speed of 1,400 revolutions per minute. The gear reduction is 6 to 1, the first reduction being obtained by the back gear shaft and amounting to 4.8 to 1, and the second reduction resulting from the difference in the sizes of the two sprockets for the slow-speed roller chain and amounting to 1.25 to 1. At their rated capacity the motors deliver about 4 horsepower each. The batteries, which are located under the car seats, are of the lead-lead type. There are 44 cells, each of which provides an initial voltage of 2.1 and a final voltage when near discharge of 1.7. The rated capacity of the complete battery is 86.4 amperes for four hours, giving approximately 29,000 watt hours available on a normal charge.

Efforts have been made to introduce storage-battery cars for lighter traffic on main lines of railroad, although so far no great headway has been made in that direction. On March 6, 1913, for example, a car equipped with nickel-steel batteries made the run from New York to Boston via the New York Central Railroad from New York to Albany and via the Boston and Albany Railroad from Albany to Boston, a distance of about 307 miles.[1] This car is 49 feet 8½ inches long over drawbar, 9 feet 1 inch over drip rail, and 12 feet 6 inches from rail to top of ventilators. It is equipped with 225 cells of nickel-steel alkaline batteries for power and five cells for light. These batteries are placed under the car in two compartments strongly reinforced with structural shapes and riveted to the underframe. The car is equipped with four 20-horsepower, 75-ampere, 200-volt, series-

[1] Electric Traction, April, 1913.

wound motors. The wheels are driven by gears placed on the inside exterior of the hubs, the ratio of reduction being 2.5:1. There are two series-parallel controllers, one on each end of the car, with four series and three parallel positions. All power wires are carried in conduit securely fastened to the underframe. This car is equipped with M. C. B. couplers and standard height of drawbar, locomotive type of pilot at each end, and air whistle at each end It is also equipped with a straight air-brake system. using a motor-driven compressor. The interior finish is of ash and polished bronze. The body is divided into two compartments, passenger and baggage. The passenger compartment is 30 feet 2 inches long, with 16 cross reversible seats, two stationary cross seats, and two longitudinal, seating one and three passengers, respectively. The baggage compartment is 11 feet 10 inches long, with sliding door on either side. The total seating capacity of the car is 51 passengers.

The trucks are of a modified diamond-frame type and are made up of standard shapes and flat plates. The wheels are chilled iron, 33 inches in diameter, and are free to rotate independently of each other on the stationary axle. The truck pedestal springs are double coil, while the body springs are double elliptic.

The car without battery and passengers weighs 48,235 pounds; standard battery, 8,525 pounds; auxiliary battery, 8,525 pounds; light battery, 266 pounds; accessories on car, 500 pounds.

The table herewith contains some interesting information regarding the car and the trip which it made from New York to Boston.

Condensed Report, New York-to-Boston Run, March 6, 1913.

Actual running time, 11 hours 6 minutes 51 seconds (11.115 hours).
Total distance (from time-table), 306.71 miles.
Average miles per hour, 27.6.
Total number of kilowatt hours, 369.1.
Average kilowatt hours per car-mile, 1.2.
Total ampere hours, 1,303.
Average ampere hours per car-mile, 4.25.
Average ampere hours per ton-mile, 124.
Average voltage, calculated from ampere hour and kilowatt hour, 283.
Maximum speed, 42 miles per hour.
Average of accelerating current, 203.7 amperes.
Total charging time on run, 3 hours 27 minutes (3.45 hours).
Total ampere hours from charging, 973.
Average charging current, 353 amperes.
Average charging voltage, 429.
Total kilowatt hours charging, 522.

Weather conditions: Rain from Grand Central Station to Poughkeepsie; light snow from Poughkeepsie to Hudson; heavy snow from Hudson to Chatham; high cross wind and drifting snow from Chatham to Springfield; 6° above zero from Springfield to Boston.

Gasoline and gas-electric cars.—The gasoline car, as such, has never been regarded as likely to become available in ordinary street railway service, although a place has been found for it in interurban work, and, of course, more particularly on parts or branches of steam railroads. The makers of one leading type of gasoline car for track service, with mechanical drive, reported that in April, 1913, some 138 were in use on 50 different railroads in the United States and foreign countries. Other makes were also in use but not in any considerable number in America. Of recent years a good deal of attention has been given to gasoline cars with electric drive, in which the engine operates an electric generator, whose current is transmitted to electric motors geared to the driving axles, instead of the engine being connected to the axles by mechanical gearing. The work in this field has been done chiefly by one large electrical manufacturer and has resulted in the production of a type that is in use on several branch and interurban lines. Sixty of these cars are reported as in regular daily service, of which 12 were on the "Dan Patch" line of the Minneapolis, St. Paul, Rochester & Dubuque Electric Traction Co. At the fifth annual meeting of the International Railway Fuel Association in Chicago, in May, 1913, Messrs. S. T. Dodd and B. H. Arnold presented data as to operating conditions and results with such cars on the Frisco lines and the "Dan Patch" lines. The table for the latter is given herewith as an example of performance on an interurban line with a very fast schedule. The trailers hauled consisted of a mixture of passenger, freight, and work cars. The cost of heating, supplies, and maintenance of equipment included also the cost for these trailers. The longest maximum grade of 1.5 per cent is about 2 miles, and there is one stretch where the grade averages 1.37 per cent for a distance in excess of 4 miles. In addition to the station stops, there are two compulsory stops at railroad crossings at grade and one drawbridge stop.

"Dan Patch" Line—Minneapolis, St. Paul, Rochester & Dubuque Electric Traction Co.—Cost of Operating Gas-Electric Motor Cars from Jan. 1 to Aug. 31, 1912.

Motor car-miles, 216,498; trailer car-miles, 75,948; total car-miles, 292,446.
Per cent of time trailers hauled, 35.5.
Number of motor cars in service, 8.
Length of line, miles, 37.34.
Maximum grade, per cent, 1.5.
Schedule time for express trains, 1 hour and 17 minutes.
Average distance between stops for express trains, miles, 3.734.
Schedule speed of express trains, miles per hour, 29.1.
Schedule time for local trains, 1 hour and 35 minutes.
Average distance between flag stops for local trains, miles, 1.067.
Schedule speed of local trains, miles per hour, 23.6.
Gallons fuel used per motor train-mile, 0.758.
Gallons fuel used per car-mile, 0.527.

	Cost for one year.	Average cost per motor train-mile.	Average cost per car-mile.
		Cents.	*Cents.*
Total	$39,139.71	18.08	13.38
Wages of crew	12,056.95	5.57	4.12
Fuel (naphtha)	17,622.26	8.14	6.03
Lubrication (gas engine)	1,141.56	0.52	0.39
Journal oil	77.77	0.04	0.03
Supplies and car heating	1,389.03	0.64	0.47
Maintenance of electrical equipment	1,949.81	0.90	0.67
Maintenance of cars and trucks	1,394.56	0.65	0.47
Shop expense of heating	3,507.77	1.62	1.20

In the latest cars of the gasoline-electric type, the car body is built of steel and is designed for the greatest lightness and strength. The front end of the car is rounded to reduce train resistance to a minimum when operating at high speeds. Either center or rear entrance is provided to meet the requirements of traffic in various localities. The cars are built in lengths running from 40 to 70 feet over all, and weigh from 40 to 50 tons complete. The interior of the car is subdivided into passenger, smoker or second-class, baggage, and engine room. The width of the car is 10 feet over all, full advantage having been taken of standard steam railroad clearances, and the cars have a seating capacity which may run as high as 95 or 100 passengers per car, depending upon the interior arrangement.

The power plant in the engine room at the front end of the car consists of an 8-cylinder, 4-cycle gas engine with a speed of 550 revolutions per minute, direct-connected to a 100-kilowatt, direct-current generator. The generator is built essentially to meet motor-car service and is therefore designed for a wide range of current or voltage, so that the output may be varied from 400 amperes at 250 volts to 125 amperes at 800 volts.

The trucks are of an equalized, swing-bolster type, suitable for the high speeds obtainable with this type of car. One, the motor truck, is designed for carrying two driving motors. The other is a standard light-trailer truck. The motor truck is generally placed under the forward end of the car and carries the weight of the engine-room equipment in addition to the motors. In such a case as this, about 60 per cent of the weight of the car is on the driving wheels. In some cases, however, the motor truck has been placed at the rear end of the car, under the passenger compartment, and under this condition approximately 50 per cent of the weight of the car is on the drivers.

The car is equipped with two 100-horsepower railway motors. These are commutating-pole motors and are suited for wide variation in operating voltage. The gearing is specially selected for the service. The gear ratio is low enough so that the highest maximum car speed will not develop excessive rotative speed of the armatures; at the same time it is high enough to obtain the requisite starting effort without imposing excessive overloads on the motors. The car is designed for operation from one end only. The engineer's seat is located at the righ-hand front window of the engine room, and controller and throttle handles are placed directly in front of him. The controller is a convenient combination of engine and generator control, with the different levers placed vertically above each other and operating at practically the same center line. The highest of these levers is the throttle lever, which controls the supply of gas to the engine, and as a consequence the speed and power of the engine. Directly beneath this is the electric-control handle. On the first part of the range of this handle the two motors are connected in series, and the whole current of the generator passes through each of them. Successive steps raise the generator voltage from about 250 volts on the first step to about 700 volts on the seventh step. By moving the controller, to the next step the voltage is reduced to about 250 volts, and at the same time the connection between the motors is changed, putting them in multiple with each other. On the remaining steps the two motors are running multiple, dividing the generator current between them, and each actuated by the full generator voltage. This voltage is raised in successive steps up to a maximum of about 800 volts on the thirteenth step. Two final steps, in addition to this, are suitable for particularly high speeds on level track.

The engine-generator set is started by admitting compressed air to the cylinders. This is done automatically on the first opening of the throttle. As soon as the engine turns over, and the first charge of mixture is exploded in the cylinder, the air is automatically shut off. Air reservoirs, which supply air for the brakes and whistle and for starting the engine, are charged by an air compressor driven from the main crank shaft of the engine. A small independent engine-generator set is supplied for furnishing the lights, and a separate compressor connected to this engine is used for charging the reservoirs in case they are entirely empty.

In Europe the most extensive experience with electric-drive gasoline cars has been on the Arad-Csanad Railway in Hungary. This road has been operating gasoline cars since 1905. At the present time, the cars are running approximately 1,000,000 car-miles per annum, and have a total record of over 5,000,000 car-miles. This road's records of cost of operation and maintenance of such equipment are probably more complete and extensive than those of any other railroad, and show an average cost of maintenance of 2.5 to 3 cents per car-mile. These cars have recently been introduced into this country, and several are already in use. The car is 56 feet long over bumpers and 9 feet 6 inches in width, and is divided into first-class, second-class, engine, and baggage-room compartments.

Center-entrance cars.

The center-entrance car seems to have made a very distinct place for itself during the period 1907–1912, but is still in its earlier stages as to the determination of standard features. This may be seen from a consideration of some of the types thus far evolved and put into service. Certainly among the most notable of these is the "stepless" or low-step class.

New types in Cleveland.—In 1913 the Cleveland (Ohio) Railway Co. added 50 new center-entrance motor cars to its equipment, which represent a marked departure from the center-entrance trail cars put in operation by this company in the fall of 1912. While the same effort was not made in designing these new cars to obtain a low floor in the seating space, attention was directed to the height of the first step from the pavement, which, as a result, was reduced from 15 inches to $12\frac{1}{16}$ inches. The over-all length of these new cars is 2 feet more than that of the trail cars, which additional length was not enough to provide for the motorman's cab in one end of the body. Partly for this reason the seating capacity was reduced from 65 passengers in the trail car to 59 in the motor car. This reduction in seating capacity is also accounted for in part by the additional width required in the entrance well because of the new arrangement of entrance and exit doors. The low-step height from the top of the rail to the entrance well also made it necessary to provide two steps from the well to the car-floor level. These motor cars are operated either singly or in two-car trains, and are provided with four motors of sufficient capacity to pull trailers. Their principal dimensions are as follows:

Length over all, 51 feet.
Length of body, 50 feet.
Truck centers, 26 feet.
Wheel base, 5 feet 6 inches.
Step heights, $12\frac{1}{16}$ inches, 12 inches, $7\frac{5}{16}$ inches.
Floor to top rail, 2 feet 8 inches.
Width over side plates, 8 feet 2 inches.
Width over sash rail, 8 feet $4\frac{3}{4}$ inches.
Height inside, 8 feet.
Height at entrance, 9 feet $7\frac{5}{16}$ inches.
Passengers seated, summer, 59.
Passengers seated, winter, 58.
Passengers standing, 65.
Standing room in entrance well, 20.
Wheel diameter, 26 inches.
Total weight of complete car, 44,280 pounds.

The design provides for a single-end, center-entrance, low-step, arched-roof car body, built with an all-steel underframe and side girders, and a composite body and roof framing. The side framing up to the sash rail is formed of a plate girder extending around the entire car body from one side of the center-entrance doors to the other. The body bolsters of these cars are of special design, and are built up of two pressed-steel plate channels to form the web members to which the top and bottom cover plates are securely riveted. The channels are formed of $\frac{1}{2}$-inch steel plates with holes punched from the webs to reduce the weight. The top and bottom plates are $\frac{5}{8}$ inch thick and 9 inches wide. At each end of the side girders which terminate at the corner posts the latter are made continuous across the car, forming both corner posts and roof carlines. These are constructed of two 2-inch by 2-inch by $\frac{3}{16}$-inch angles.

The method of ventilation adopted as standard by the Cleveland Railway Co. on all plain arched-roof cars is also used. A small ventilating louver, running the full length of the car body, is supported on aluminum brackets with louvers at the sides, allowing air currents to play through from all directions, creating a suction over ducts coming up through the roof under the small ventilating-louver deck. The brackets are reinforced at the place where the trolley stand and base are supported. Thirteen ducts leading from the inside of the car to the roof under the ventilating louver are covered on the under side of the head lining by neat polished-bronze registers. These roof openings are placed in the center of the ceiling, running longitudinally. With this system it is impossible for snow, sleet, or rain to reach the interior of the car.

Eighteen windows are provided on the "devil-strip" side of the car body and 14 on the entrance side. These, as well as the three windows in the rear end of the car and the two windows in the motorman's cab, are single sashes arranged to drop into pockets between the window posts. All sashes are made $\frac{5}{8}$ inch thick with brass stiles and cherry rails.

The entrance and exit doors at the center of the car are built of 1-inch solid cherry with two glass panels and brass wearing strips. These doors are equipped with ball-bearing door hangers and are operated electropneumatically by a push button set in the fare-box stand convenient to the conductor. These doors slide into parallel pockets provided in the panel between them. A natural red-cherry wood finish, slightly stained to insure a uniform color, is used in all interior panelings and moldings. The latter are free of all corners liable to collect dust and dirt.

The car is designed for single-end operation; consequently the rear vestibule is available for seating space at all times, and the motorman's cab is permanently in the front vestibule. The cab occupies a maximum width of 3 feet 2 inches. The seating arrangement for passengers is somewhat different from that in general use, being a combination of cross and longitudinal seats. The cross seats have pressed-steel pedestals. Six cross seats occupy each end of the car body, with longitudinal seats encircling the rear vestibule and extending the full length of the "devil-strip" side of the car. The location of the conductor's stand in the entrance well makes it possible to utilize the opposite side of the car at this point for seating space. A longitudinal seat has been installed in the well with a removable panel at one end to provide for the forced hot-air heater during the winter months. By this arrangement provision was made for a maximum seated load of 59 passengers and a total seated and standing load of 144 passengers. In order to improve conditions for standing passengers, a continuous handrail supported on brackets 5 feet 11 inches above the floor runs the full length of the car on the longitudinal-seat side. Pipe stanchions are also provided on each side of the aisle at the break between the car-body floor level and the entrance well.

At the time the mechanical department was considering the design of these cars, this company had already adopted the method of fare collection in which a combination pay-as-you-enter, and pay-as-you-leave principle was used. In the center-entrance trail car, however, the conductor stood opposite the center-entrance doors in the center of the car body. Hence he blocked the center aisle, and it was also necessary that he stand with his back to one end of the car. In the new motor cars the conductor stands with his back to the panel between the center-entrance doors, which permits him not only to clear the entrance aisle but to observe passengers in both ends of the car body. In operating this car with the combination system of fare collection the conductor collects fares from passengers entering one end of the car and from those leaving the opposite end of the car. The conductor's stand is mounted on a slightly elevated platform, which protects him not only from the accumulations of snow and moisture in the entrance well during bad weather but also against being crowded away from his station by passengers. This method of fare collection was adopted in order to relieve congestion in the downtown district during the evening rush hours and has been found to work quite satisfactorily.

The system of illuminating these new cars was adopted as a result of an exhaustive test in car illumination made by the Cleveland Railway Co. during 1911 and 1912. In this test the illuminating system which gave the highest efficiency was furnished by five 100-watt tungsten "Mazda" lamps in satin-finish reflectors mounted in special shade holders. These lamps were in series and were mounted on the ceiling along the center line of the car, and a spare lamp was so connected with a selector switch that it could be instantly cut into the circuit in case of failure of any one of the five lamps regularly lighted. In the new cars, however, 92-watt lamps securely fastened in electric pendants and provided with deep reflectors were installed. Five of these lamps were spaced uniformly along the center line of the car ceiling with the spare lamp beside the one over the entrance well. The selector switch was placed in the panel just back of the conductor's stand.

In addition to the usual buzzer system installed with push buttons at convenient locations on the posts between the windows, a light signal was provided. The signal circuits were so arranged that the signal lamps in the motorman's cab indicate the position—open or closed—of the center-entrance doors in addition to showing the signals operated by means of the conductor's push button. Both the signal and lighting systems were also arranged for trailer operation, a coupler socket and drum switch being provided just inside the rear buffer.

The brake apparatus of these center-entrance motor cars is novel in that two 8-inch by 8-inch air cylinders were employed, one operating the brakes on each truck, although the hand brake operates on both trucks. A single lever having equal arms was used with one end connected to the push rod of the cylinder and the other end to the truck-brake pull rod. The two cylinders were in turn connected by an air pipe to insure uniform pressure on both pistons and consequently equal brake power on both trucks. The brake cylinders were placed horizontally against the large 12-inch channels each side of the center-entrance well and were hung from the steel underframing in forged-steel stirrups.

A hand-brake system was installed, with the usual drop-handle brake staff on the step side of the motorman's cab. The hand-brake rod was hung below the step side and side sill and extended to a long lever operating in a horizontal plane and placed just in front of the center-entrance well. The other end of this lever was connected in turn to an extension of the forward lever of the air-brake apparatus by a slotted link. From this connection a cable was carried under the center-entrance well and connected to the pull rod of the rear-truck brake.

A commutating-pole type of motor having the following characteristics was adopted: Forty horsepower on one-hour rating; gear ratio, 57:15; and to operate on 26-inch wheels. It was the aim of the railway and the manufacturers to produce a motor which could be adapted to a 26-inch wheel.

The trucks are of special design. They were constructed to be equipped with two motors each and to operate with 26-inch, one-wear, rolled-steel wheels on axles of 4½-inch diameter at the motor bearings and 5-inch diameter at the gear seat and with the railway standard 3¾-inch by 8-inch journals. Roller side bearings and ball center bearings were also included. The wheel base of the truck is 4 feet 10 inches, and the height from the rail to the top of the complete center plate is 21 inches with the car body in place.

New types in Pittsburgh.—After experimenting for a period of nearly two years, the Pittsburgh Railways Co. has adopted as standard a type of center-entrance car that possesses many unusual features. Foremost among these are the small motors and wheels that permit the car floor to be kept down to a point which in the center of the car is only 24¾ inches above the rail. Another feature is the use of a front exit as an auxiliary to the center doors with which the car is furnished. This makes a compromise type, because the two doors at the center are not used to provide a separate exit and entrance, but are flexible in their use, so that, if desired, both may be used as an entrance or both as an exit. There is no definitely assigned path for the movement of passengers in and out of the car, the conductor directing this in accordance with the immediate needs.

This radical departure from the usual custom of handling passengers along rigidly prescribed lines is stated to have been adopted on account of the peculiar conditions existing in Pittsburgh. In that city it is customary, on outgoing cars during the rush hour, for all passengers to be loaded at three or four points within the restricted business district. They may be carried for several miles before any unloading takes place, and then are dropped off in small groups as on an ordinary suburban line. The exact reverse of this process takes place with inbound cars, and in consequence the use of both center doors for an entrance or for an exit is of distinct value in decreasing the time of stops.

The front-exit door is under the control of the motorman, and it provides a means for short-distance riders to get off the car at congested loading points without interference from incoming passengers. It also eliminates the necessity for the conductor to leave the center doors open and unguarded when he gets off to throw a switch or to signal to the motorman at steam railway grade crossings. A mirror is installed over the right-hand front window at each end of the car so that the motorman can see what the conductor is doing without having to turn around. The mirror also informs the motorman of passengers moving to the front of the car to make use of the front-exit door, and is set at the maximum possible height so that there is no danger of the motorman's view being obscured by the heads of standing passengers.

When the car is in operation the conductor stands beside a stanchion placed in the exact center of the car, and entering passengers pass on either side of him in case both center doors are used for entrances. On this stanchion are two handles for operating the doors so that the conductor has no need to move out of his position. The fare box is carried in a frame of gas pipe hung from the center stanchion. It may be swung around on its support to either side of the car, and when the car is in operation it is located immediately in front of the open doors, thus providing a clear space in front of the passengers who make use of the folding seats along the doors on the blind side of the car.

There are only two handles for operating the doors, and they are carried on the center stanchion. Each of these handles operates one of the two doors on the entrance side of the car. When the car changes ends and the doors on the opposite side of the car are to be used, the operating rods which extend over the center stanchion to the operating mechanism of the door are disconnected, swung around to the other side of the car, and connected to the operating mechanism of the opposite doors. The connections are made by easily removable pins, and in order to avoid any possibility of connecting the doors wrongly, one of the two operating mechanisms on each side and one of the rods are painted red, and the others are painted black.

The destination signs are located in the monitor over the center doors, and at each end of the car is a large, illuminated route-indication sign in a wooden frame.

The seating arrangement of the car is a combination of cross and longitudinal seats. The ends of the car are provided with circular seats, no bulkheads being installed. There is also provided a single seat attached to stanchions at each end of the car. The stanchions are used primarily to support a folding seat for the motorman and to act as guides for a curtain at the motorman's back to keep the lighted interior of the car from obscuring his view at night. Folding seats are located in front of the unused doors on the blind side of the car.

There is a ramp in the floor between the trucks and the center. This gives a rise of 3 inches and, together with a transverse ramp between the step and the longitudinal center line of the car amounting to $\frac{11}{16}$ inch, makes the minimum floor height $24\frac{3}{4}$ inches. This is divided into one $15\frac{1}{4}$-inch step from the ground and one $9\frac{1}{2}$-inch interior step. At the front exit the floor height of approximately 2 feet 5 inches is divided into three steps, of which two are interior, of about $8\frac{1}{2}$ inches each.

A notable innovation is the use of immovable semicircular seats at both ends of the car. The controller at each end is set below the seat and the shaft is extended up through the seat and through a pipe railing slightly above the ordinary height of an arm rest. When the car is being operated in either direction, the controller and reverser handles are put in place on the shaft of the controller drum, the motorman standing back of the fixed seat at the front end. The controller-drum handle extends through the hollow reverser shaft so that both handles have the same center. Through the pipe railing also extends the shaft of a mechanically operated sander, and at the right of the motorman another piece of pipe railing affords a support for the removable hand-brake wheel and air-brake handle. At the rear end of the car all of these handles are removed, leaving the pipe railings with no projecting pieces and permitting passengers to use all of the end seats.

All doors are of the interior combined swinging and sliding type standard on the Pittsburgh Railways, and are mechanically operated by short handles on interior stanchions. The approximate net door opening is 2 feet 4 inches. While the extreme car width is 8 feet 2 inches, the ends are reduced to 7 feet. The cars, complete with double-end control and couplers at each end, weigh 38,000 pounds.

Cars on Long Island.—No section of a city previously neglected or undeveloped has grown with more astonishing rapidity than the portion of Long Island eastward of Brooklyn and reached by the newer bridges, particularly the Queens Borough, passing high over Blackwell's Island. The demand for transportation has been intense, and is being met in some instances by the newest types of center-entrance, stepless cars. The Manhattan & Queens Traction Corporation, which operates between Fifty-ninth Street, New York, and Jamaica via Queens Borough Bridge, Long Island City, Elmhurst, and Forest Hills, has 25 center-entrance cars. The general design is very similar to that devised and used by the Brooklyn Rapid Transit System. The seating capacity is 52, and the weight, fully equipped, 20 tons. The builder could have made the car a little lighter, but certain restrictions in connection with operation over the bridge made it desirable to have a construction with more than the usual factor of safety. The general dimensions of the cars are as follows:

Length over vestibule ends, 45 feet.
Length over buffers, 45 feet 6 inches.
Truck centers, 22 feet.
Height from rail to top of roof, 11 feet.
Length of center-entrance platform between two compartment bulkheads, 7 feet 1 inch.
Width over side sheathing, 8 feet 4 inches.
Width over eaves, 8 feet 4 inches.
Width over belt rail, 8 feet 5 inches.
Width over window sill, 8 feet 5⅝ inches.
Width of aisle, 26 inches.
Length of seat, 36 inches.
Wheel base of truck, 4 feet 6 inches.

The bottom framing is of steel with a 6-inch 8-pound channel for the bottom member of the side girder. The side girder is of 29½-inch by ⅛-inch plate with a 3-inch by ½-inch bar for the top member. The 6-inch channel is made in one piece which is bent down at the center for the platform or well. The sills are 4-inch, 7½-pound **I**-beams spaced approximately on 3-foot centers. The vestibule-end frame and the center-entrance platform are reinforced with diagonal braces. The end sill is built up of steel plates and rolled shapes. The vestibule ends are sheathed with sheet steel and have buffer shields. Cast-steel bolsters are used.

All posts of the body framing are made of 1½-inch by 2-inch by ¼-inch T's bent around from side sill to side sill and forming carlines, and all have post-ash strips to serve for sash guides. The upper sash is stationary, while the lower sash is arranged so that it can be raised. The center-entrance posts are of T's and pressed channels with a plate and channel over the door to provide compression members in the side-girder construction. The vestibule ends have wooden posts with outside bar reinforcements.

The roof is of plain-arch type. The T-posts which form the carlines have ash roof nailing strips bolted on the top and sides for the attachment of the ceiling. The roof boards are ⅜-inch tongued and grooved poplar. The vestibule-end roof is supported on ash carlines bent to shape. Below the sash rests the cars are finished in ⅜-inch mahogany sheathing, which is applied between the posts with an allowance for ½-inch air space between the outside girder plate and this wainscoting. All the metal trim is of highly polished bronze.

The flooring in both ends of the car is sloped downward for 3 inches from the bolster to the center entrance, while the floor of the center well is sloped 1 inch downward toward the door.

The pair of center doors on each side are of the sliding type with glass panels; they operate simultaneously with the steps. Hinged doors for the use of the motorman only are provided in the vestibules.

Cars in Brooklyn, N. Y.—The center-entrance trolley car developed by the Brooklyn Rapid Transit Co. is a double-end, straight-bodied type, with low-step passenger entrance and with two exits located at the center of the car and arranged for the collection of fare as the passenger enters. The car floor at that point is 14 inches above the rails at the threshold, with 2 inches of ramp to the center. Inside the car is a 10-inch riser from the central platform subfloor or well to the center aisle on each side. This aisle has a ramp of 6 inches in 8 feet 6 inches to the bolsters, from which points the floor is level.

The center entrance and exits are divided by stanchions and railings to give a clear entrance of 32$\frac{11}{16}$ inches in the center and a 21⅜-inch exit on each side. The pivoted railing, which can be swung from one side of the car to the other, depending upon which set of doors is being operated, divides the incoming from the outgoing passengers. The lower panels of the side doors are of clear wired glass to permit unobstructed observation by the conductor while the doors are closed. Soft-rubber buffers are attached to the doors to avoid injury to passengers and damage to their clothing. A locked swing door 21½ inches wide and 5 feet 5 inches high is provided at each end of the car for the exclusive use of the motorman. This door is made of welded steel with one drop and one fixed sash.

The car seats 58 passengers, making the deadweight per passenger 671 pounds. The original seating plan called for 16 cross seats of reversible type with a 26-inch aisle between, longitudinal seats at the center doors, and curved seats at the ends. This general plan has been retained as giving maximum seating capacity without congestion at the center, but ingenious improvements have been made in seats which are in or out of service, according to the direction of running. In the first car of this type, the end seating was so arranged that the section directly behind the motorman was hinged upward at each end when the cab doors were swung out for service, and the outer ends of the seating near the cross seats were raised in like manner with the change in direction. The newer end seat is a semicircle seating eight passengers and made of four hinged segments, each quarter circle consisting of a long segment near the motorman and a short segment which opens outward to a supporting piece on the adjacent cross seat. Before the motorman makes up the cab by bringing out the two swinging sashes he turns over the end of each half circle of seating, thereby doubling its thickness and halving its length. The upwardly hinged seats were discarded to save time in changing from one end to the other. The curved end seats are finished on both sides, and to avoid the tearing of clothing they are made with screws which are inserted transversely through the slats.

In the first car the seats opposite the center door were arranged to slide horizontally under the adjacent longitudinal seats on the higher floor level. This has been superseded by a new arrangement in which each half of the seat is brought into place by swiveling it downward on a rod carried on the upper floor between the side of the car and an aisle stanchion. When not in use, each half is kept vertical by a double-acting lock which fits into a retaining bar. Both seat halves are alike except that one carries a folding leg which is automatically locked into place when the seat is up. The seat with the leg is dropped first. These seats and the pair of center doors not in service are interlocked both mechanically and electrically to prevent the improper opening of the door.

The cross seats are 34 inches wide. They have but one pedestal each, the other ends of the seats being carried by pressings between the posts. The arm rests are of mahogany. At each side on the upper level near the door is a longitudinal seat with space for three passengers.

The motorman's cab presents a departure from the original design in that the folding doors have been replaced by a lighter, cheaper, and faster combination, consisting of two swinging sashes, which are carried only to the height of the seat backs, and an intermediate curtain which is drawn down behind the motorman to screen him from the light of the car interior. The cab is prepared for service by folding the curved seat, next swinging out the two sashes to an angle of about 45°, and then inserting the separator or tiebar, which when not in use is kept hinged in an upright position on one of the swinging sashes. These sashes have curtain grooves, the curtains being placed in moldings in the bulkhead above so that when the sashes are opened in position to form the cab the grooves will be in the proper place to receive the curtain fixtures.

Each car is mounted on two "maximum-traction" trucks with 4-foot 6-inch wheel base, equipped with 28-inch driver wheels and 21-inch pony wheels. The driver axles are of heat-treated carbon steel, with $3\frac{1}{2}$-inch by $7\frac{11}{16}$-inch journals, and the pony axles of open-hearth hammered steel, with 3-inch by $7\frac{1}{2}$-inch journals.

The traction equipment consists of two motors rated at 40 horsepower at 500 volts and 50 horsepower at 600 volts. These motors are wound for field control. The gear ratio is 61:14. On tapped field they are capable of giving a maximum speed of 25 miles per hour and on full field a maximum speed of 21 miles per hour. The motors have a maximum vertical height of 2 feet 1 inch and a maximum width of 4 feet $\frac{7}{16}$ inch. Compared with older motors, these dimensions mean a saving of 2 inches' clearance below the axle.

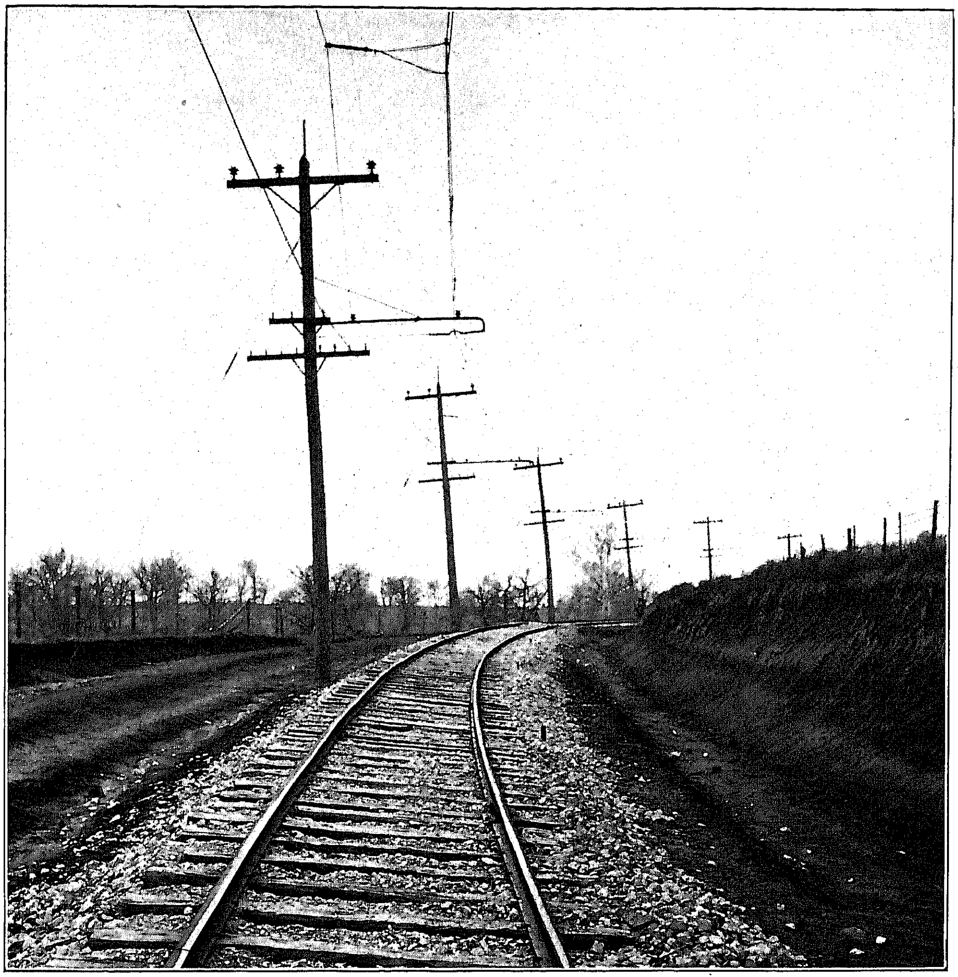
Fares and transfers are collected as the passengers enter. The entrance railings lead the passengers to the conductor, who is stationed at his pedestal in the center of the well. The pedestal is a revolving device with a change table on the top, where fare is paid by the passengers. The weight of the latest car, including drawbar fittings, etc., is 28,900 pounds, compared with 39,550 pounds for the first car.

NEW TYPES OF ELECTRIC SUBURBAN LINES.

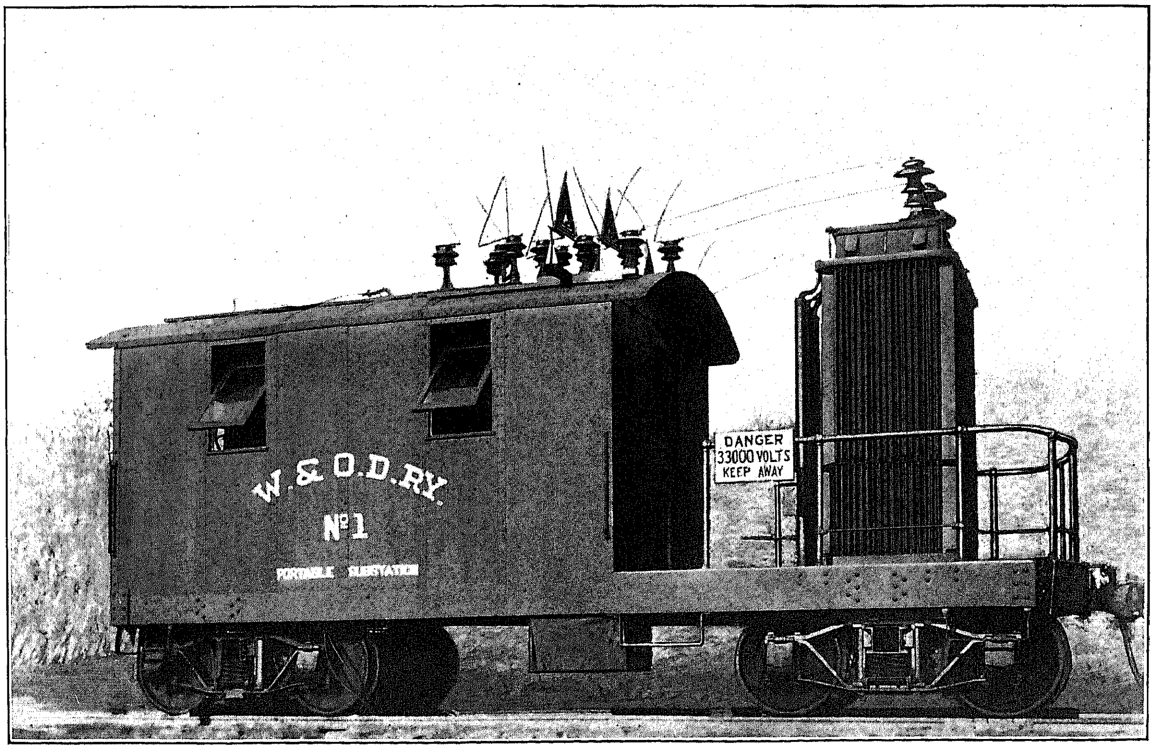
At the time the previous report on street railways was issued there was a marked tendency to use direct current for city and limited suburban traffic and to use alternating current for interurban lines. The direct-current voltage employed was then around 600 or 700 volts. In the interval, direct-current voltage has been carried up to 1,200 to 1,500 volts, and a number of new lines using this voltage have gone into operation. On the other hand, several new lines have been equipped by the earlier methods, such as the 40-mile suburban extension of the Waterloo (Iowa), Cedar Falls & Northern Railway, which uses 600 volts direct current. More interest attaches, however, to the new types operating at a direct-current voltage twice as high, with many incidental economies and advantages. A few examples may be cited.

Oakland, Antioch & Eastern Railway, Cal.—Interurban electric systems are fast supplanting the steam railway in the vicinity of San Francisco. Among these may be mentioned the Peninsula System between San Francisco and San Jose, and the Key Route extension between Oakland and San Jose, each 50 miles in length; the Ocean Shore Railroad from San Francisco to Santa Cruz, covering a distance of 65 miles, operated part way as a steam road; the Fresno & Monterey Railroad, which very materially shortens the distance from the center of the San Joaquin Valley to tidewater; the Northern Electric Co.'s line from Sacramento to Vallejo, which, with the Suisun and Vacaville extensions, is over 60 miles in length; and the Oakland, Antioch & Eastern Railway. This last company operates a regular train service between Oakland and Bay Point, Contra Costa County, a distance of 31 miles, and through trains between Oakland and Sacramento, 85 miles distant.

Starting from the main Oakland depot at Fortieth Street and Shafter Avenue, the Oakland, Antioch & Eastern line extends up Shafter Avenue and across the north arm of Lake Temescal. Thence it winds up Shepherd Canyon on a 3 per cent grade to the Redwood Peak Tunnel, which pierces the Coast Range for a distance of 3,458 feet. Most of the tunnel is through solid rock, and all that is not is lined with



CATENARY LINE CONSTRUCTION, KANSAS CITY, CLAY COUNTY & ST. JOSEPH RAILWAY CO.



PORTABLE SUBSTATION; WASHINGTON, D. C. & OLD DOMINION RAILWAY.

(Face p. 380.)

reinforced concrete 24 inches in thickness on the sides and 18 inches in the arch. Located at the east portal is the largest of the five substations. From Bay Point across Suisun Bay to Chipps Island the Oakland, Antioch & Eastern Railway proposes to build a bridge 10,000 feet in length and 70 feet high over the navigable portion of the stream. The estimated cost of of this bridge is $1,500,000, and work has begun on it. While this bridge is being constructed, a ferryboat is used to transport trains across Suisun Bay. This boat is noteworthy, as it is one of the few gas-operated boats in the world used for car transportation.

Across Yolo Basin the road is carried on a trestle 13,900 feet long. In the center of this trestle a drawbridge has been erected over Montezuma Slough. There is a clear opening of 109 feet, and the draw is operated from land by remote control, a 1,200-volt, 15-horsepower motor supplying the power, which is transmitted by submarine cable. All of the roadbed between Chipps Island in Suisun Bay and Sacramento has been completed. It is heavily ballasted and oiled to prevent dust. The rails are ferrotitanium alloy, 70 pounds per yard, A. S. C. E. standard. The Oakland, Antioch & Eastern enters Sacramento by the M Street Bridge, owned partly by that company, partly by the Northern Electric Railway, and partly by the counties of Sacramento and Yolo. Between towns a speed of 60 miles per hour is maintained.

Current is supplied by the Great Western Power Co., whose main power house is on the Feather River, 18 miles north of Oroville. Five substations are required for the service of the Oakland, Antioch & Eastern Railway. They are 17 miles apart and are located at the east portal of Redwood Peak Tunnel, at Concord, at Montezuma, at Main Prairie, and at Glide's Levee, respectively. The standard substation equipment consists of one 750-kilowatt motor-generator and switchboard. These comprise one 1,300-volt, interpole, direct-current generator rated at 514 revolutions per minute; one 1,080-horsepower, synchronous, 11,000-volt, 3-phase, 60-cycle motor, with one 18-kilowatt, 125-volt, direct-current exciter on the shaft; one switchboard equipped with synchronous-motor panel; one direct-current general panel; and three direct-current feeder panels. The substation at Redwood Peak, which provides for the heaviest load, is equipped with two complete sets of this equipment, while each of the other four substations has but a single set. There is also one portable substation of 350-kilowatt capacity.

The overhead catenary construction is 1,200-volt No. 000 trolley, $\frac{7}{16}$-inch steel messenger, with a 600,000-circular-mil aluminum feeder. Pending the completion of the bridge across Suisun Bay, current is being transmitted from Bay Point beneath the surface by two submarine cables.

The company operates fourteen standard cars and two parlor cars. The former are 56 feet in length over all, 10 feet wide, and are divided into express, mixed passenger, and smoking compartments. There is seating capacity for 50 persons. The cars are provided with electric fans for summer and electric heaters for winter. Electric lights overhang all seats. The parlor cars, attached to the express trains, will seat 60 passengers and are provided with well-appointed buffets. Each car is equipped with four 140-horsepower, 1,200-volt, direct-current, interpole railway motors, control, and two dynamotor compressors. The trucks are of standard "trunk-line" type.

The heavy freight traffic is handled by two 50-ton electric locomotives, each equipped with four 160-horsepower, 600/1,200-volt direct-current interpole motors, electrical control, and two dynamotor compressors.

Nashville-Gallatin (Tenn.) 1,200-volt line.—A 1,200-volt direct-current interurban line has been completed and put in operation between Nashville and Gallatin, Tenn. It traverses a densely populated district northeast of Nashville and bordering the Cumberland River Valley for a distance of 27 miles. Except in a few places, the entire line is built on a private right of way, paralleling the old Gallatin turnpike, which passes through what is known as the "Blue Grass" district of Tennessee. Throughout the entire length the territory is urban in character, with a population averaging 800 people to each square mile on each side of the road.

This new line of the Nashville-Gallatin Interurban Railway sprang immediately into prominence as an interurban road because of the fact that it is the longest in the state of Tennessee. It is built with 70-pound rails laid on standard-size white oak ties spaced seventeen to 33 feet. The ruling grade is 3 per cent, and the maximum curvature 6 degrees, except on that portion of the city lines of the Nashville Railway & Light Co. by which access to the business district of Nashville is obtained.

The private right of way averages approximately 50 feet in width, except in places where this was not sufficient for heavy cuts and fills. To fix the alignment of all curves which are spiraled, 4-inch by 4-inch oak-post monuments are set in concrete at all points of spiral, at points of compound curves, and at points of tangency. These permanent monuments are set 7½ feet from the center of the track and painted with black letters on a white background. They show the degree of curve and elevation of the outer rail, and the monuments at points of spiral and at points of compound curve give the length of each. Practically all the heavy excavation is in solid rock, which made grading exceedingly expensive. Standard roadway sections include a 12-foot roadbed with 1½ to 1 slopes on embankments and a 14-foot roadbed in excavation. The standard slope in all rock cuts is ¼ to 1.

The overhead trolley and transmission lines are carried on a single line of 35 feet, 7½-inch-top chestnut poles set at 100-foot intervals with the face 8 feet from the center of the track. Two of the three No. 4 conductors constituting 33,000-volt, alternating-current, 3-phase transmission line are carried on a 5-foot two-pin cross arm near the top of the pole, with the third-phase conductor on a pole-top insulator. This arrangement permits a 52-inch spacing between the three conductors. This transmission line extends from the generating station of the Nashville Railway & Light Co. at Nashville to the substation at Hendersonville.

Pipe mast arms are attached to the pole below the transmission line so as to give 18 feet clear head room between the top of rail and trolley. Just below the mast arm a standard cross arm is applied which varies in length according to the number of signal wires. This cross arm also carries the feeder on the insulator nearest the trolley. The telephone circuits are on bracket insulator pins below this cross arm. Both the trolley and feeder wire are of No. 0000 round copper, and the latter is strain-guyed every quarter of a mile and at approaches to all important curves.

The initial rolling stock for this 27-mile road included four interurban passenger cars and one baggage car. The passenger cars are 50 feet 6 inches long over all by 8 feet 5¾ inches wide. The bodies are of arched-roof design, for single-end operation, with under frames of composite construction which are under- and over-trussed.

The car body is divided into a passenger and a smoking compartment, and the latter also serves as seating space for colored passengers. The motorman's cab is of good size, being 6 feet 3 inches over all, to provide space for light baggage. A two-leaf folding door on the right side of the cab permits the colored passengers to enter the compartment reserved for them without passing through the car. A 42-inch sliding door on the opposite side of this vestibule serves for loading and unloading the baggage. The rear platform is equipped with a single 36-inch two-leaf folding door and a triple-tread coach step on the right side. The total seating capacity is 54, with seats for 16 passengers in the smoking and colored-passenger compartment, and 36 in the main compartment. The interior finish, including linings, moldings, doors, and sash, is of cherry, mahogany finished, and the seats are upholstered in rattan, with brass fittings.

Four 600-volt motors are included in the car equipment. Two motors are connected in series for 1,200-volt operation, and are capable of 50 miles per hour. A change-over switch in the motorman's cab permits the motors to be operated in multiple when the car passes from the 1,200-volt interurban line to the 600-volt street railway line in the city of Nashville. The express and baggage car is arranged for double-end operation, and like the passenger car is built with a composite underframe and an arched roof.

The most novel feature in the auxiliary equipment of this express car is an installation of two small power cranes to facilitate the handling of heavy freight. The underframing of the car body was reinforced to carry the additional strains imposed by the operation of these cranes. The hoist standard is composed of two sections of channel iron fitted into castings on the car floor, and just above the 7-foot sliding doors. These castings form a pivot for the vertical member, which in turn supports a horizontal boom. Inside of the channels of each crane a 3-inch air cylinder with a 24-inch piston stroke has been installed with the cylinder at the bottom, which permits the piston to travel upward.

A sheave wheel is mounted just above this air cylinder and on a level with the horizontal member of the crane. This wheel and a second sheave wheel set in the end of the piston rod are employed in raising and lowering loads to and from the car. The horizontal boom is built of two plates placed so that a pulley may be set between them, five pairs of bearing notches being provided for this purpose. The location of the pulley on the boom depends on the weight of the load and its distance from the car door. With a normal air pressure on the car, the hoist is capable of lifting 800 pounds. Each hoist is pivoted beside the sliding doors so that it may be swung out through the door opening. A hose-and-pipe connection to the air-brake reservoirs supplies air to the hoist cylinder, which is operated by a straight-air valve attached to the side of the upright member of the hoist.

Pittsburg-Butler high-voltage railway.—The Pittsburgh & Butler Street Railway was the fifth single-phase interurban road in the United States to substitute 1,200-volt direct current for the single-phase alternating system. The road affords an unusually good opportunity for a comparison of the relative merits of the two methods of propulsion, as it had five and one-half years of single-phase operation. With the 1,200-volt direct-current apparatus the same car bodies are used, and the new motors are of the same nominal rating as the former ones. Under these conditions a reduction in power consumption per car-mile of not less than 15 per cent has been shown by a comparison of power-house records for the months of August, 1913, and August, 1912. In addition, the mechanical and electrical force at the car house was reduced 54 per cent, exclusive of car washers, etc.

The total length of road operating in 1913 on 1,200 volts was about 28 miles. For a distance of 6 miles, from Etna to the Pittsburgh terminal, the cars operate on the 600-volt trolley over the tracks of the Pittsburgh Railways. At the Butler end of the line the substation of the Butler Passenger Railway, an affiliated company, is utilized to supply current to 4¾ miles of track.

The track gauge is 5 feet 2½ inches, conforming to that of the Pittsburgh Railways. The road for the greater part of the way passes through a hilly country, making operation especially severe on account of the extra power requirements and the unusually heavy duty on the equipment. There are three grades averaging from 7 per cent to 9 per cent, while frequent lesser grades range from 3 per cent to 5½ per cent. A grade of 9 per cent is encountered near Etna, and at a point about 5 miles north of the Gibson substation, near Bryant, the south-bound cars ascend a 6 per cent grade with an 8-degree curve. The road from Etna to Butler is single track throughout, and with the exception of short stretches through the larger towns, is over a private right of way.

Electric energy generated at the power house at Renfrew, 5¼ miles from the Butler terminal, is transmitted to two rotary converter substations at 22,000 volts, and there is transformed to direct current at 1,200 volts. The power house at Renfrew, which was originally used to supply single-phase current to the trolley through transformer substations, has been adapted to supply 3-phase current to the rotary substations. This power house contains one 1,500-kilovolt-ampere and two 750-kilovolt-ampere horizontal steam turbine units connected to deliver 3-phase, 25-cycle, 6,600-volt current. By a rearrangement of the single-phase transformers, this current is now stepped up to 22,000 volts, 3-phase, for transmission. Besides the supply to the 1,200-volt substations at Mars and Gibson, alternating current is transmitted to the 600-volt substation of the Butler Passenger Railway at Butler. The same 3-phase lines provide power for the lighting circuits in that city and in towns along the line.

There are two substations containing identical equipment, one at Mars, adjoining the car house, and one at Gibson, near the city of Etna. A transmission line of three No. 4 copper wires extends the entire length of the system, the original single-phase line having been utilized by the addition of a third wire. The 1,200-volt circuit also was reinforced by additional feeders, and the rail bonding was, of course, renewed throughout.

The substation and car house at Mars are approximately 17 miles from Etna and 16 miles from Butler. The distance to the Renfrew power house is about 10 miles. The two equipments in each substation are in exact duplicate, each consisting of a 300-kilovolt-ampere, 25-cycle, 1,200-volt synchronous converter, a 300-kilovolt-ampere, 3-phase, oil-cooled transformer, and the necessary switchboard with feeder and starting panels. The incoming 22,000-volt circuits are protected by a four-tank aluminum lighting arrester. These lines are also provided with choke coils and disconnecting switches. On the high-voltage side of each transformer are three single-pole, 22,000-volt, 300-ampere automatic oil switches, installed in brick cells and hand operated by means of switch levers mounted on a slate panel.

The transformers are Y-connected, with 740-volt secondaries. Four 2½ per cent taps are provided in the primary side, thus allowing adjustment between 19,800 volts and 22,000 volts. A one-half-voltage tap is provided on the secondary side for starting purposes. These transformers are of the standard railway type with high inherent reactance.

The synchronous converters are rated at 300 kilowatts, 750 revolutions per minute, 1,200 volts, and are provided with the usual end-play, speed-limit, and brush-raising devices. These machines are capable of 50 per cent overload for two hours and three times normal load momentarily. A separate switch panel is used for starting from the alternating-current side. The direct-current switchboard consists of four standard 1,200-volt panels, including a synchronous converter panel for each machine and two feeder panels. A standard 1,200-volt, direct-current aluminum lightning arrester is provided for each of the outgoing feeders. One machine is sufficient to handle the entire load except for a few hours in the morning when the first cars are leaving the car house. The proper taps are used on the primary side of the transformer to give 1,300 volts on the direct-current side of the rotary converter.

The Gibson substation is 1 mile from the end of the line at Etna, and contains exactly the same equipment as the Mars substation.

As mentioned before, at the Butler end of the road for a distance of 4¾ miles the trolley is fed from the 600-volt substation of the Butler Passenger Railway Co. The present equipment of the substation includes two 500-kilowatt synchronous converters, which have ample capacity to take care of the maximum load requirements of both systems.

Eleven of the 13 original single-phase car equipments have been replaced by 1,200-volt, direct-current apparatus. These cars include 10 combination passenger and baggage cars and 1 express car. The passenger cars have passenger and smoking compartments, and all but 2 are provided with baggage compartments for light freight and package express. The total seating capacity is 52 passengers, and the estimated weight of the car with average seated load is 37 tons. This is a reduction of 6 tons from the weight of the same car equipped for single-phase operation. This reduction was made possible by the elimination of the transformer and duplicate alternating-current, direct-current control, and a reduction of 1,500 pounds in the weight of each motor.

The principal dimensions and weights of these cars are shown in the following statement:

Length over all, 51 feet 3 inches.
Width over all, 8 feet 1½ inches.
Height from track to roof, 13 feet 6 inches.
Distance between truck centers, 27 feet 6 inches.
Wheel base of truck, 6 feet 8 inches.
Weight of car body, 30,000 pounds.
Weight of trucks, 17,000 pounds.
Weight of electrical equipment, 22,000 pounds.
Weight of brakes and compressors, 1,800 pounds.
Average passenger load, 4,000 pounds.
Total weight, 74,800 pounds.

The electrical equipments of these cars are identical, with the exception of the gear reduction on the express car motors. The four motors used on each car are of the internally ventilated, commutating-pole type, rated at 100 horsepower on 600 volts.

The installation of the apparatus on the cars is an unusually good example of car equipment, and several features deserve special mention. All wiring is in conduit, and every conduit is a straight pipe, which simplifies the pulling in of wires and cables. Special cast-iron outlet boxes are suspended directly over the resistance grids, and the grids themselves are carefully insulated to prevent damage from snow. The motor leads are also well protected from injury by use of cast-iron terminal boxes on the car and special wooden terminal blocks on the motor case. Each lead is covered with rubber hose armored with brass wire, and the outlet box is placed near the center of the bolster to obtain maximum flexibility. Hangers and boxes, and in fact all accessories, are interchangeable on all cars.

Among the changes made in the cars to adapt them to direct-current operation is included that in the roof covering. With the single-phase equipment, a grounded copper sheathing was used on the car roof to ground a broken trolley wire. For direct-current operation the cars are covered with canvas, and the trolley deck running the entire length of the car is insulated for 1,200 volts.

The change from 6,600 volts single-phase to 1,200 volts direct-current was accomplished without interruption to traffic. After the first two cars had been equipped for 1,200 volts, the system was changed over from Butler to Mars, passengers being transferred to the single-phase cars at Mars. On August 1, 1913, direct current was thrown on the entire system, and four additional cars were put in service on the regular schedule. Since the inauguration of the 1,200-volt service no trouble of any kind has developed in the operation of the electrical equipment.

TRACK CONSTRUCTION.

Maintenance of track is one of the large and serious problems of the street railway industry. The subject has been covered fully in previous reports, but these necessarily dealt with conditions subject to constant change. Of these changes and developments no more striking or interesting illustration could be given than the history of the girder rail so largely in use in American cities for street railway service. At its meeting in Atlantic City in 1913, the American Electric Railway Engineering Association adopted four standard girder rails for tangent and curved tracks on paved streets. In commending this action, Mr. Martin Schreiber, engineer of maintenance of way of the Public Service Railway Co. of New Jersey, noted the fact that three years earlier no fewer than 200 different types of rail were found to be in use in the industry.

Data on girder-rail development.—While it was true that "live" sections were considerably less than this in number, still many of the sections in use then were available, and rolls and equipment were yet on hand for the manufacture of many of them. It is only fair to concede that electric railway engineers had fully realized that standard rails would eventually mean better service and cheaper track, but the situation had not been altogether in their control. Besides, the development in the electric railway industry, especially of equipment, was not mature, and the time has hardly been ripe for standard rails until now.

Mr. Schreiber traced the development of the standard girder rails that were finally proposed by the engineering association. The first actual design of the grooved girder rail for paved streets was that proposed as standard by the committee on rails and rail matters of the American Street and Interurban Railway Association, presented at the 1907 convention. There were two 9-inch and two 7-inch grooved rails, the former weighing 137 pounds and 122 pounds to the yard, respectively, and the latter weighing 122 pounds and 98 pounds to the yard, respectively. In the same report were also recommended two 7-inch and two 9-inch tram rails, together with designs for 7-inch and 9-inch guard rails for use with both grooved and tram sections. The committee on way matters for 1910 approved the principles outlined in the previous reports, but submitted in detail for consideration new designs for 7-inch and 9-inch grooved girder rails. The reasons for submitting alternative designs were that the committee considered the previous sections to be too heavy and their first cost too high.

In 1911 the same committee revised the work of all preceding committees and confined its attention to the design of a 9-inch grooved girder rail, submitting a thorough and careful analysis of the principles which governed each detail. The design submitted by this committee comprised one radical departure from any other rail section that had previously been in use or proposed, in that it provided for a tapered web. The reason given by the committee for the change in design was a mathematical one. It was explained that in the case of wagon loads on the tram, or when cars sway from side to side, the web acts as a cantilever and its stability is directly proportional to the cube of the cross section at the base. The 9-inch rail submitted by the committee, therefore, had about two and one-half times the stability of the rail with the straight web nine-sixteenths inch thick, although containing practically the same quantity of metal. The committee of 1911 was very anxious that the 9-inch girder rail proposed by it should be adopted as standard, but the convention decided that it would be better to prepare designs for both the 7-inch and 9-inch rails for straight track and the 7-inch and 9-inch rails for curved track, rather than a design for one rail only. Accordingly, the committee on way matters for 1912 approved the

9-inch design submitted by the 1911 committee and also presented three additional designs covering a 7-inch grooved rail for straight track and a 7-inch and a 9-inch guard rail for curved track. Although these four designs appeared to be very nearly what was required, the committee on standards did not approve the recommendations of the way committee, principally on account of the contour of the throat of the guard rail, and referred the whole question back for further action of the way committee reporting to the 1913 convention.

The 1913 committee on way, guided by the experience of all previous committees and the large number of discussions that had occurred, was determined to produce satisfactory designs. Accordingly, it submitted at the 1913 convention plans for four standard rails, including those for straight and for curved track, both 7-inch and 9-inch. Not only were these designs approved by the committee on standards, but the action was also ratified by the convention, and the rails are now the standard for the association. Thus, after six years of continuous work, there are four standard rails. It is interesting at this time to compare the original rails, as produced by the 1907 committee, with the rails recommended by the committee of 1913. If one compares only the weights of the rails, there is very little difference. Closer examination, however, develops the fact that a great deal has been accomplished. In the first place, in 1907, 16 rail sections were proposed as standard, in 1913 only 4. This is due to the fact that the 1913 committee felt justified in eliminating the tram rail altogether, and to the further fact that it proposed only one 7-inch and one 9-inch rail instead of two of each. At any location where a tram rail would be allowed by the municipal authorities, it seemed that a T-rail would be just as efficient from the latter's point of view, and certainly greatly to be preferred to any other type of rail from the railway company's standpoint. If the T-rail were not approved, it seems that there would be no reasonable alternative but the grooved girder rail.

One of the 9-inch grooved rails of 1907 weighed 137 pounds and the 9-inch grooved rail of 1913 weighed 134 pounds—a difference of only 3 pounds. There are, however, material differences in design. The contour of the head is modified, in that the width of the wearing surface of the later rail is $2\frac{1}{8}$ inches as against $2\frac{1}{4}$ inches in the old rail. The depth of the bevel of the new design is $\frac{1}{16}$ inch greater than in the 1907 rail, and the length of the bevel is $\frac{1}{8}$ inch greater. The advantages of these changes accrue principally to railways that are still using a narrow tread of wheel, in that they allow longer life of the rail before ridges appear on the wearing surfaces. The over-all width of the head of the 1913 rail is $\frac{3}{8}$ inch greater than that of the 1907 rail, and the depth of the lip below the head is $\frac{1}{8}$ inch less. These latter changes were made to afford better paving and vehicular conditions.

Another important improvement in the 1913 rail is the increase in depth of the groove from $1\frac{1}{4}$ inches to $1\frac{7}{16}$ inches. This point was very difficult to decide, on account of the early practice providing a depth of only $1\frac{1}{8}$ inches, while some of the rail rolled during the last few years has a depth of $1\frac{1}{2}$ inches. It is very desirable to have the groove deep to give maximum wearing value to the head; nevertheless, this has been thought undesirable by many, because of vehicular traffic and of the cutting down of the fishing depth, especially in the case of the 7-inch rail. The design of the web of the new rail is entirely different from that of the old in that the taper of the 9-inch rail is $\frac{1}{2}$ inch at the top and $\frac{5}{8}$ inch at the bottom. This arrangement increases the stability, tending to prevent corrugation, which has been a serious menace, particularly in the last few years. The width of the base of the heavy 1907 9-inch rail was $6\frac{1}{2}$ inches, while that of the rail proposed by the 1913 committee is only 6 inches. In the committee's opinion, it was only necessary to design a base that would be of sufficient width for bearing, and at the same time the narrow base allowed more uniform rolling.

Generally the same arguments apply to grooved guard rails, but in the latter there is a distinct tendency toward a change of contour and an increase in the width of the throat. The design of the throat of the guard is altogether a question of construction of the equipment. The equipment has been considerably developed since the 1907 committee's deliberations were presented. In fact, it is now generally conceded that it is necessary to provide a guard that will take care of a standard A. E. R. E. A. flange and a wheel base varying from 4 to 6 feet, with radius of curved track varying from 40 feet upward. The fact that the throat in the guard rail had been designed only $1\frac{1}{4}$ inches deep seemed to be an advantage because the wear on the guard is not apt to come on the bottom of the groove but rather on the sides, and the decrease of the groove allows an increase in the depth of the guard, which is desirable on account of the large strain on the guard by the wheels of cars taking curves.

T-rail construction.—A very large amount of T-rail construction is in use throughout the country, and there is abundant evidence as to its persistence as a type. Its prevalence can best be shown, perhaps, by considering one part of the country. A description of conditions in Connecticut, by Mr. R. C. Cram, formerly of the Connecticut Co., furnishes the required data, while the report of the public utilities commission of Connecticut for the year ended June 30, 1912, is one of the very few state reports giving data as to type of rails and pavements used by street railways. An analysis of the report shows that the 10 operating companies in the state reported a total of 1,055 miles of single track. Five companies, operating about 150 miles, reported no girder rail whatever, thus confining the use of girder rail to the other five, four of which reported only 7 miles of girder rail about evenly divided between the tram and the groove girder types.

Of the total mileage in the state, approximately 93 per cent is laid with 40-pound/95-pound T-rail, 4½ per cent with 70-pound/96-pound tram girder, and 2½ per cent with 85-pound/125-pound groove girder. Substantially 91 per cent of the girder-rail mileage is confined to the lines of the Connecticut Co., with about 60 per cent of this confined, in turn, to the lines in Hartford. In that city practically all of the original tracks were laid with tram girder rail, and these must be replaced with groove girder, as occasion arises, in accordance with an agreement between the city and the company made several years prior to the time when the Connecticut Co. acquired control of the property.

With regard to pavement, an analysis of the report shows a total of 336 miles of single track paved with various types of pavement. Included in this total, however, are 26 miles of stone ballast (backfill above ties) which is not properly to be considered as pavement except for purposes of accounting. The net mileage of paved track is therefore found to be 310 miles, or approximately 29 per cent of the total mileage of tracks reported. The Connecticut Co. reported 288.1 miles paved, or substantially 93 per cent of the total paved mileage.

The following table shows the percentage which the mileage of each type of pavement used by the Connecticut Co. forms of the total paved mileage of that company:

Connecticut Co.—Percentage Distribution of Paved Mileage.

CLASS.	Per cent of total paved mileage of company.
Macadam	67.1
Brick	13.0
Cobble	5.6
Asphalt	5.4
Belgian and granite block	4.9
Wood block	1.8
Bituminous—Macadam and bitulithic	1.1
Granitoid	0.8
Hassam	0.3

If the mileage within the limits of the city of Hartford be excluded, it appears that about 90 per cent of the paved mileage in Connecticut is laid in conjunction with T-rail.

As to the T-rail and pavement situation on the lines of the Connecticut Co. in the largest five cities in the state, the two tables immediately following are significant:

Connecticut Co.—Percentage of Mileage Paved and Percentage of T-Rail in Largest 5 Cities.

CITY.	Population.	Mileage in city limits.	Per cent paved.	KIND OF RAIL—PER CENT.		
				T-rail.	Tram girder.	Groove girder.
New Haven	133,605	67.0	86.0	100.0	....	....
Bridgeport	102,054	40.0	99.0	88.0	8.0	4.0
Hartford	98,915	50.0	96.0	10.0	50.0	40.0
Waterbury	73,141	34.0	79.0	88.0	8.0	4.0
New Britain	43,916	13.0	81.0	100.0	....	....

Connecticut Co.—Percentage Distribution, by Classes, of Paved Mileage Within City Limits of Largest 5 Cities.

CITY.	Macadam.	Brick.	Wood block.	Cobble.	Granite block.	Belgian block.	Asphalt.	Bitulithic.	Granitoid.
New Haven	52.0	13.0	4.0	10.0	0.5	7.0	1.5	5.0	7.0
Hartford	76.0	....	0.5	....	....	....	23.5	....	....
Bridgeport	61.0	16.0	20.0	....	2.0	....	1.0	....	....
Waterbury	6.0	21.0	1.0	52.0	11.0	....	....	9.0	....
New Britain	76.0	....	....	....	....	....	1.0	23.0	....

Note.—Belgian and granite block are not separated in state report. Bitulithic included under "Bituminous macadam."

In commenting on the first and third of these tables it is to be noted that macadam, in general, is the predominating pavement in the largest cities, as well as in the total paved mileage in the state. The exception noted for the city of Waterbury, where cobble is found to predominate, is accounted for mainly by the fact that much of the mileage in that city is laid on quite heavy grades, where macadam is exceptionally hard to maintain between the rails, and also because it has generally been the custom to pave the tracks there with cobble whether the roadways outside are paved or not.

The objects sought were to provide a minimum flangeway for the maximum wheel flange in use, to eliminate both groove rail and special groove or nose block, to provide a reasonably smooth crossing for team traffic at right angles to the tracks, and to provide facilities for wagon wheels to turn out from the tracks with comparative ease as well as with safety. It is believed that these objects have been and are being satisfactorily attained. This is particularly worthy of note because the commission is the sole authority on the type of track construction to be used in streets, and its approval must be had in all cases of track reconstruction. In this connection it should be stated that while the commission, in many instances, has approved the installation of T-rail, it recognizes the fact that at times there may be some locations where groove girder rail would be preferable, also that the width and grade of streets and the volume and character of traffic must be carefully considered in any decision as to which rail may be the more suitable under all conditions. In only one case so far, however, has the commission ordered a groove-rail construction, after full investigation.

Methods of paving.—As to pavement, the experience of the Connecticut Co. has probably been about as extensive as that of any of the other important systems. The railways in Connecticut have only a limited control over the type of pavement laid within the track area, since they are required by statute to lay the same type of pavement in their section of the street as that laid by the municipalities in the other part of the street. Nevertheless, they are not required to lay a pavement which is more expensive, nor are they absolutely held to the same type provided they lay a pavement which is considered equally good as compared with that laid outside the railway area. As a rule, however, the practice is to lay the same type, the work being done by the same contractor under a separate contract with the railway company. There have been a few exceptions to this rule, where the contractor's bid for the railway work was in excess of the bid for the rest of the roadway.

The predominance of macadam may be accounted for, in general, by its low first cost, the abundance of trap rock, and the fact that until the advent of the automobile a good water-bound macadam roadway was sufficient to withstand all but the most concentrated traffic in the immediate centers of the cities and towns. Moreover, it can be well laid even with a 5-inch, 80-pound T-rail, is maintained at moderate cost, and is somewhat more adaptable for use with the T-rail than with the girder rail. It is thought that the tendency toward oiled macadam and the more recent forms of bituminous macadam will result in the continued use of such macadam pavement in connection with tracks where traffic is moderate and where the width of streets does not cause excessive wagon tracking at the gauge lines.

According to the tables, brick pavement is next in extent. The older types consisted mainly of the small vitrified shale pavers, while the more recent ones are constructed with the present standard paving brick or block. They have been laid almost universally with cement-grouted joints on a sand cushion and a 6-inch concrete base. The quite general adoption of brick in the past as a pavement may have been due to the fact that until the introduction of the modern types of grouted granite and wood-block pavements it was the only alternative to asphalt in the so-called "permanent pavement" class, and asphalt has never found much favor in Connecticut cities.

As a track pavement, brick has proved quite satisfactory up to the point where traffic following the rails becomes excessive. It can be well laid in connection with T-rail, and is quite readily replaced after street openings and track repairs, though at considerable loss of material. The use of any form of special "nose" or groove blocks, however, has proved very unsatisfactory. Moreover, it should be stated here that these installations of groove blocks were made only under vigorous protest on the part of the company.

While cobble appears as next in importance in the first table, it will suffice to say that its use is generally confined to tracks in outlying districts, often on grades, in streets as yet otherwise unpaved. As a material for this purpose cobble is very good, providing firm foothold for horses, and preventing the rutting between the rails which usually occurs, after a time, where tracks are merely back-filled with earth or gravel.

Asphalt occupies a rather anomalous position in the list, since it is confined practically to one city. What little remains in tracks elsewhere will no doubt be displaced within a year or two. There is every reason to believe that much of the disfavor in which asphalt is held as a pavement for railway streets in Connecticut is the result of its installation in connection with tracks which were too old and were in no way as substantial as the modern construction. Later installations would indicate that asphalt can be laid and fairly well maintained, under moderate traffic, in connection with a heavy groove girder rail. It is thought, however, that the well-known troubles incidental to asphalt maintenance are sufficiently grave to make its installation undesirable and something to be avoided as far as possible.

Belgian block occupies about the same position as cobble in so far as its value for use as a pavement is concerned, and it is rapidly disappearing.

Granite block as a track pavement has until recently been in little use in Connecticut. Such as there was consisted of the old type of 8-inch-deep blocks, laid on sand, mainly with sand joints. Within the past two or three years the value of the modern type of comparatively smooth granite pavement began to be appreciated, and several installations have been made. The construction is composed of a moderately soft New Hampshire granite, with blocks about 5 inches deep, 4 inches wide, and 8 inches to 10 inches long, laid with 1:1 cement-grouted joints on a $1\frac{1}{2}$-inch sand cushion and a 6-inch concrete base. This construction has been adopted usually where grades and very heavy traffic are found, with 7-inch 95-pound T-rail.

In connection with grouted granite-block pavement a new method of construction is coming into use. The procedure consists simply in splitting old 8-inch to 12-inch granite blocks into from two to three parts, each about 4 inches deep, and laying them with the new split faces upward, all other parts of the construction being the same as with new granite. The cost of this method is, of course, much less than with new block, and the resulting pavement seems to be practically as good.

Wood block has been steadily coming into favor in Connecticut. The relative importance of this kind of paving is not properly shown in the first table, because several extensive installations were in progress at the date of the report on which the table is based. As a paving material it rivals granite, even when wear is considered, and is more readily cut in around obstructions. While trouble is had at times from the tendency of the blocks to buckle under certain conditions, such defects are usually quite easy to remedy. The result is a smooth, clean, quiet pavement, which is highly desirable, especially in residential sections. It is adaptable to both T and groove rail, and may be quickly replaced after track repairs, even in the winter time, with the least loss of material. It has been customary to lay this pavement on a 6-inch concrete base with 1-inch sand cushion and sand joints.

The experience with bituminous macadam is not of sufficient length to enable a more definite opinion to be formed than that expressed in reference to ordinary macadam. With regard to "bitulithic," however, it has been found that it is quite satisfactory for streets carrying a moderate traffic. When laid in conjunction with T-rails it has been deemed advisable to place wood or granite block at either side of the rail heads. Several large installations have been made, the earliest two in 1906. Neither of these required any expensive attention from the contractor at the expiration of the five-year guarantee period. In fact, after seven years they appear to be good for an indefinite period. The most objectionable feature would seem to be the dependence upon the contractor for such repairs as may be necessary from time to time.

Granitoid is a pavement with a concrete surface, usually laid out in block form on top to prevent slip. Where installed in Connecticut no attempt was made to interpose any form of joint or shock absorber between the rail and the pavement. It presents a neat appearance, but the block formations soon disappear under traffic. It is thought that perhaps for light traffic it may answer quite well, especially when first cost and comparative ease of repair are considered; but for heavy traffic following the rails, especially T-rails, it may be unsuitable.

In any track construction in paved streets the pavement is perhaps the most important feature, in relation both to total cost of the track construction and to the use of the street by the public. Mr. Cram believes that much of the objection which has been raised to the T-rail construction should more properly have been brought against the type of pavement used in connection with that rail. This observation is the result of experience in connection with several agitations over the T-rail question in Connecticut cities, where it has been found that agitation ceased after a T-rail installation had been made in accordance with the Connecticut Co.'s standard cross sections to replace the old tram-girder and asphalt-pavement construction. In fact, the new T-rail construction has been praised highly by both the press and members of civic associations.

Track in various cities.—With the idea that descriptive details of types of track to be used and installed during 1913 would be of general service, an article was published early in that year giving some interesting data for several cities, which are here quoted.[1]

The city track of the Waterloo, Cedar Falls & Northern Railway Co. is built with 12 inches of 1 : 3 : 5 concrete under the rails and carried up over the base of the rail. This is done to make sure that the concrete is in contact with the base of the rail, for the reason that if it were poured only up to the base, the space under the rail would not be filled and there would always be moisture there. Mr. T. E. Rust, chief engineer for the company, estimates that the ties are the weakest part of the track and uses them only to keep the rails in gauge. They are spaced 3 feet center to center and set in the concrete, which, rather than the ties, is depended on to support the rails. Seventy-five-pound T-rails and twin bonds are used.

The joint construction is of especial interest. It is made with angle bars and with a piece of old rail 24 inches long, embedded in the concrete in inverted position and in intimate contact with the rail base. This plan was adopted because of the fact that the concrete under the rail joint gradually wears away, and if the wearing surface is made of steel instead of concrete the joint stays in its originally perfect condition much longer. It is very essential, however, that the piece of inverted rail shall be in intimate contact with the rail, and in order to obtain this perfect contact, the piece of old rail, before the pouring of the concrete, is held up against the track rail by means of two pieces of No. 8 iron wire looped around both sections and over a $\frac{1}{2}$-inch steel rod laid on top of the running rail and provided with two large set screws. When the wires are fastened tightly around the whole joint, these set screws are turned down, bringing the section of old rail into perfect contact, and the concrete is then poured in.

The Virginia Railway & Power Co., Richmond, Va., is using 9-inch girder grooved rail with electrically welded joints, together with a crushed stone and concrete substructure. A 6-inch layer of crushed rock is laid below the ties and 3 inches above their base, and 6 inches of 1 : 3 : 6 concrete is poured on this, bringing the level of the concrete over the base of the rail. Tie-plates and screw pikes are used. The ties are dimensioned 6 inches by 8 inches by 8 feet, and spaced at 2-foot centers.

The Toledo Railways & Light Co. is using 6-inch, 100-pound, open-hearth T-rail on sawed white-oak ties, untreated, 5 by 8 inches, 7 feet long. The ties are on a 3-inch bed of stone ballast, $\frac{1}{2}$ to $1\frac{1}{4}$ inches, under which is a 5-inch base of 1 : 4 : 6 concrete. The rail joints have four-hole angle bars with 1-inch bolts. The rails are 60 feet long, laid with staggered joints,

[1] Electric Traction, May, 1913.

and with 30 ties per rail. The stone ballast is applied flush with the top of the ties and rolled with a 10-ton steam roller. On top of this is placed a $1\frac{1}{2}$-inch layer of concrete to keep the ballast and roadbed free from water from the street. Neither tie-plates, tie-rods, nor rail braces are used. On the inside of the rails a wood filler block is placed next to the web. Next to this is placed a wood nose block, or one which has a corner beveled off so as to provide a flangeway for car and vehicle wheels. The paving blocks are laid on a $\frac{3}{4}$-inch cushion of sand, and the joints are filled with sand instead of the customary pitch or tar filler. Track drains are put in the centers of both tracks at depression breaks in the grade of the street.

The web of the rail along the outside of the track is filled with rather dry mortar, against which the paving blocks are laid. The tracks are laid at 9-foot $2\frac{1}{4}$-inch centers, with the inside rails $\frac{1}{2}$ inch higher than the outside rails to fit the contour of the street surface. Cross bonds are installed 200 feet apart. The 3-inch ballast well tamped under the ties is enough to surface the track thoroughly and to distribute the weight quite evenly to the concrete base.

The Twin City Rapid Transit Co., Minneapolis, Minn., is using 7-inch, 91-pound T-rail laid on creosoted ties which rest on a bed of gravel 2 inches thick over a sub-base of crushed rock or gravel. The space between the ties is filled in with 1:3:5 concrete up to the base of the rails. On the track laid in unpaved streets, the company uses 5-inch, 80-pound T-rail supported on pine ties with gravel ballast under the ties and dirt filling between them. Bonds No. 0000 of U shape with the terminals welded to adjacent rails are used, the welding being done by means of an acetylene torch. The joints on the unpaved track are 26-inch four-holes. On paved streets the company uses a 7-inch, 91-pound rail, and all joints are cast welded. The paving in and between tracks is cut granite, laid on Portland-cement concrete. The paving outside of the tracks is generally of the same kind as put down by the city. Where practicable, the company prefers to put a couple of courses of granite blocks as stretchers along the outside of the rail. There is some objection to these rows of granite outside of the rail, except in the case of asphalt paving.

In the standard track construction of the Cleveland Railway Co., 7-inch, 95-pound T-rail is used, supported on steel ties spaced at 4-foot centers, with a 1:2:6 concrete substructure. A concrete stringer is laid under each rail to a depth of 12 inches and with a width of 12 inches. Between the rails the concrete is laid to a depth of $1\frac{1}{2}$ inches below the ties. The joints are built with a 1-inch by 4-inch steel plate, 30 inches long, riveted on each side of the rail with four $1\frac{1}{16}$-inch rivets on each side of the joint. These are put in hot under a pressure of about 100 tons, supplied by a 100-foot air compressor, and are riveted by a riveting machine. The base of the rail is welded by the thermit process. Steel ties are placed under the joints. In purchasing the rails, Mr. C. H. Clark, engineer of way, specifies 0.75 to 0.90 per cent of carbon, 0.10 per cent of titanium, 0.20 to 0.30 per cent of silicon, and not more than 0.80 per cent of manganese. Specifications are also drawn up for the rivets. In order to make certain a joint which will conform to the rail, the composition of the joint is specified the same as that of the rail. The drilling of the rails is required to be such that a driving fit of the rivets will be secured. This type of joint possesses the advantages of both the welded and the continuous joints. After the track is surfaced, the ball of the rail is brought to a true surface at all joints by the use of grinders.

The International Railway Co., Buffalo, N.Y., is using 124-pound girder grooved rail, fastened with screw spikes to 90 per cent heart long-leaf yellow-pine ties, untreated, and spaced at 2-foot centers. The substructure is made of 8 inches of 1:3:5 concrete, and a 2-inch layer of $1\frac{1}{4}$-inch crushed stone is laid between the concrete bed and the bottom of the ties. On top of this a second bed of concrete $6\frac{3}{8}$ inches thick is laid, which comes up to the base of the rail. A 4-inch farm tile is laid in a hemlock trough along the center of the "devil-strip" 8 inches below the lower concrete sub-base. The tile is covered with crushed stone, and a 3-inch by 3-inch weep-hole filled with crushed stone is left in the sub-base every 10 feet. Any water which may seep around the ties then runs through the crushed-stone layer under the ties and through the weep-hole into the draintile.

The Georgia Railway & Power Co., Atlanta, Ga., digs a trench 8 feet 2 inches wide and 20 inches deep, and the soft spongy places are filled with good material and rolled with a steam roller, if practicable. Broken-stone ballast 5 inches thick, double tamped, is laid to come $1\frac{1}{2}$ inches above the bottom of the tie. Sap pine, creosoted ties are used, and 9-inch, 89-pound semi-grooved rail in 62-foot lengths is laid with the joints staggered. After the track is surfaced on the 5 inches of broken stone, cement grout in the proportion of 1 part cement to $1\frac{1}{2}$ parts sand is poured into the ballast.

Another type of construction used in Atlanta calls for the same rails, bonds, and joints as above, but the rails are laid with the joints opposite. The roadbed is graded 7 feet 8 inches wide by 9 inches deep, and rolled with a steam roller. Longitudinal trenches are then dug under the location of each rail, 10 inches beneath the base of the rail, 10 inches wide at the bottom, and 22 inches wide at the top. Cross trenches for the ties are dug 5 feet apart, the bottoms coming at the same depth as those of the longitudinal trenches except at the joint ties, where they are 2 inches lower. The joints of the track are square. After the trenching is done, the ties are placed in the tie trenches, the rails laid and spiked, and the track lined and surfaced on blocks, thin oak wedges being used to bring it to the exact line and surface. Concrete is then poured in the track to bring it up to the proper elevation for the street pavement.

After investigating the results obtained by different street railway companies throughout the country, the Texarkana (Ark.) Gas & Electric Co. decided, in 1910–11, to use a concrete paving surface along its double-track line on Broad Street, the principal thoroughfare in Texarkana. Two years' service since the installation of this type of paving gives some idea of what wear may be expected. The paving shows no evidence of failure, and the depth of wear is negligible. To obtain these satisfactory results, Mr. W. L. Wood, jr., general manager, had a rigid set of specifications drafted for the work. During the progress of the construction, both as to track foundation and as to paving, it was closely inspected and every precaution taken to produce permanency. The track cross-section contains 6 inches of 2½-inch crushed limestone laid in a trench 19 inches deep. This was rolled with a heavy road roller, and then the track was laid. It comprises creosoted yellow-pine ties of standard size laid at 2-foot centers and 70-pound A. S. C. E. rail spiked in place, the whole resurfaced to the finished elevation. To detect the weak spots, it was customary each night, after a section of new track had been laid and opened to traffic, to couple a general utility motor car to a 100,000-pound gondola car loaded with stone ballast and to run them back and forth over the new track until all possible weak points had been found. The following day the spots in the foundation under these points were pick-tamped to surface and again submitted to the ballast-car test load before the concrete was placed.

After the skeleton track had been brought to a permanent surface and tested, an additional quantity of crushed stone was cast between the ends of the ties in double track to the height of the tops of the ties, to reduce the quantity of concrete in the finished pavement. Then the paving foundation was laid. This consisted of 1 : 3 : 5 concrete brought up to the tops of the ties. The paving surface was laid with concrete in the proportion of 1 : 2 : 4, where the aggregate consisted of 1-inch crushed stone. No wearing-surface mixture was provided, but the paving material was placed comparatively dry or of a consistency which would bring the moisture to the surface if it were tamped. After the paving surface had been accurately formed with a templet which gave a ¾-inch crown between the rails and a 1¼-inch flangeway, the surface was floated to complete the job.

Expansion and contraction were provided for by ½-inch joints spaced at 6-foot intervals. Ordinary weather boarding of a wedge section was used as the insert at the expansion joints, and after the initial set it was replaced with an asphaltum filler. To prevent breaking down the edges of the concrete paving, particularly by the cross traffic at street intersections, flat bar iron of ½-inch by 4-inch section was laid edgewise to form a curb. Under all track special work and at each joint the crushed-stone ballast foundation was poured solid with cement grout just before placing the paving foundation. A period of 10 days was allowed for the concrete to set before traffic was resumed. Natural drainage was furnished by a good sandy subsoil.

Electric arc welding of track.—On the United Railroads of San Francisco eight or nine electric-welding outfits of the portable type have been in use since the beginning of 1912, and have proved thoroughly satisfactory in every respect. Through their use the road has been able to reclaim and rehabilitate many thousands of dollars' worth of material in the repair shops, and also a very large amount of rail and special work in the streets. In the latter case, corrugations and cup-outs have been built up easily and satisfactorily, as well as plates in hardened-center special work where the points have become broken or worn.

For repairs to track and special work, the apparatus is especially economical. The road reports that, for a very nominal sum, material to the value of several thousands of dollars is reclaimed annually and its life prolonged for several years. It is impossible to estimate the exact saving on track work through the use of electric arc welding, for the reason that, while the value of a new piece of special work may be $1,500 or $2,000, the actual cost of replacing the worn-out piece will amount to considerably more when the cost of labor for installation and the amount involved in tearing out and replacing the pavement are considered. As an example, it is stated that at one of San Francisco's busiest corners complaint arose on account of the noise caused by cars running over a worn double-track section. This section cost about $1,400, and the cost of replacing it with new material would have amounted to $1,000, but through the use of the process the road was able to rehabilitate the crossing, thereby prolonging its life for possibly several years at a cost of between $75 and $100.

The feature of portability affords the greatest opportunity for saving. In many cases where welding is done at a forge or furnace by a blacksmith, by far the greatest part of the cost of the complete operation is that which is involved in dismantling the damaged piece, transporting it to and from the forge, and reassembling it after the repairs are finished. The ability to bring the welding flame to the work and to apply it from almost any direction or angle eliminates practically all of this expense, and through the localization of the welding heat it has now become possible to make "spot welds," to weld in narrow strips along crooked lines, or to operate upon material of a degree of thinness which would prohibit its being handled in a forge or on an anvil.

This accounts largely for the great variety of work done with the electric arc, an example of which is given in the list of material repaired by the electric arc on the United Railroads of San Francisco. They regularly make repairs to gear cases, motor cases, axles, truck frames, axle bearings, and brake-shoe heads, where the dowel pins have become oblong, armature shafts where the keyways and the tapered pinion seats have become worn, axle caps, brake levers, bolster castings, brake hangers, controller backs, step castings, and in fact all car material or parts which need repair. In the track department the road has used the electric arc for repairing switch tongues, frogs, and mates and for filling up cup-outs, corrugations, and low joints in both straight rail and special work.

On the Pacific Electric Railway Co., a machine similar to those used in San Francisco is reported to be kept busy and to have done exceedingly satisfactory work in building up cupped rails. It is stated to have prolonged the lives of crossings and special work from eight months to a year. It is used to a considerable extent for cutting rails and boring holes in manganese steel. The operating cost to make a weld in a rail is reported to be approximately $3, Mexican labor being used, as it has been found that the apparatus does not require any special skill after the operators have been advised how to handle it.

STREET-CAR ILLUMINATION.

A very marked improvement was seen in the illumination of street cars during the period 1907–1912. By reason of the universal use of electricity in car propulsion, the lighting has also become electrical in like degree, but it has had to pass through considerable change and evolution from carbon-filament, tantalum-filament, and graphitized-carbon lamps up to the modern tungsten.[1] It is stated that about the middle of 1913, bare or unfrosted tungsten metallic-filament lamps were already in use, with a few tantalum, on approximately 28 per cent of the cars in service, bare graphitized-filament lamps on 10 per cent, and bare carbon lamps on 60 per cent. At that time, about half a dozen installations had been made with large tungsten units and shades. Although the incandescent filament lamp has been used for the lighting of street railway cars practically ever since the electric motor cars superseded the horse or cable cars, it has not been until within the last six years that any attempts have been made to utilize the generated light to best advantage by means of scientifically manufactured shades or reflectors; and it was not until 1912 that the tungsten-filament lamp of an efficiency of 1.4 watts per horizontal candle or better was perfected to the extent of making it sufficiently rugged for street railway service. There are several reasons for this slow development. Lighting energy, being but a small fraction of the total energy used by motors, and being relatively cheap to generate, has not been considered as a field for economy. The shortness of the periods during which individual passengers use the lighting has not been conducive to progress. Furthermore, the rough usage to which lamps and shades are necessarily subjected, the low first cost of the carbon-filament lamps, and the uncertain relations between private street railway corporations and municipalities, all are reasons for delay in better car lighting.

[1] S. G. Hibben, Illuminating Engineering Society, Sept., 1913.

One of the first street cars using individual reflectors on lamps was put in service in 1900 by the Oakwood Traction Co., operating in Dayton, Ohio, although previously there may have been a few desultory attempts to equip lamp clusters with reflecting glassware. This car was equipped with center-deck, four-light fixtures, and side-wall, single-light brackets, using square-shaped alba glass shades. Cars with this equipment are still in service.

Around 1911–12 a number of traction companies installed bare 23- and 36-watt tungsten-filament lamps in place of the carbon lamps. When the majority of these new lamps had shown a life of 1,000 to 1,300 hours, progress was rapid toward the standardization of the present series lamps, and the shade, holder, and switch devices as accessories.

The lighting of street cars was previously accomplished by using bare carbon, and in a few cars graphitized-filament, lamps. It required from a dozen to thirty of the so-called 16-candlepower, 64-watt, carbon lamps in the car body, and 8 to 10 similar lamps distributed on platforms and in the headlight and designating signs. Between bulkheads the lamps were placed about 18 inches apart in line along the center deck, or studded over the whole ceiling, or else grouped in clusters of four, five, or as many as eight lamps arranged radially from single fixtures on the center-deck ceiling. Such carbon lamps usually burned five in series on the nominal 550-volt power circuit, each being rated at 110 volts.

The high current consumption of the carbon lamps, together with their poor illuminating performance, led to the substitution of, first, the metallized-filament lamps, and second, the bare 23-watt tungsten lamps in the same sockets. The former lamps proved unsatisfactory on account of filament breakage from jarring, and by reason of other objections, while the small unshielded tungsten lamps were but a temporary makeshift, on account of excessive glare and because no attempt was made to utilize the maximum amount of generated light or to direct it downward.

The most modern car-lighting equipment consists of one circuit of five tungsten lamps of the 94-watt, 78-candlepower size, arranged in line along the car ceiling, or else an arrangement of two circuits of five each of the 56-watt, 46.7-candlepower tungsten lamps. Quite often, in the cars where the 94-watt lamps are used, these are placed four in the car body between bulkheads and one over the entrance vestibule, especially if the car is of the pay-as-you-enter type. In other types of cars, such as the interurbans, there may be three units in the passenger compartment, one in the baggage or smoking room, and one in the vestibule. An additional circuit of five 23-watt tungsten lamps is used for the large types of city cars, particularly if these cars have the one circuit of 94-watt lamps. The small lamps are arranged over the steps, in the headlight, and in the illuminated designation signs.

Sometimes, but not often, the fourth size of modern lamp, a 36-watt, 26.8-candlepower tungsten-filament, is used in the car body, but the cases where the 23-watt or the 36-watt lamps are being employed between bulkheads are largely those where no new wiring or accessories are being installed and where these small lamps are replacing the carbon lamps in the old sockets or receptacles.

The four tungsten-lamp sizes mentioned above are those thus far standardized for street railway service. Their characteristics are given in the following table:

Characteristics of Tungsten-Filament Street Railway Lamps.

Watts.	Horizontal candle-power.	Watts per candle-power.	Lumens.	Average hours life.	Bulb diameter.	Over-all length.
23	17.1	1.34	168	2,000	$2\frac{3}{8}$	$5\frac{1}{4}$
36	26.8	1.34	263	2,000	$2\frac{3}{8}$	$5\frac{1}{4}$
56	46.7	1.20	457	2,000	$2\frac{5}{8}$	$5\frac{3}{8}$
94	78.3	1.20	767	2,000	$3\frac{1}{16}$	$7\frac{1}{8}$

Any of these lamps are procurable for a power-line voltage of 525 to 650, or with individual ratings of 105 to 130 volts. They are sturdy in construction, and are selected for the current which insures a uniformity of candlepower and life.

All lamps in the most modern street cars are being equipped with "downward reflecting" shades. Several forms of holders are available. These holders clamp the neck of the glass shade all around, with a firm grip that can not jar loose, and in such a way that there is no probability of breakage if a well-made shade is used.

Two main factors are the criteria of the satisfactory qualities of the lighting system—the cost and the illuminating performance. The latter consideration involves the measurable amount of foot-candle value, the quality of the light that is furnishing this foot-candle value, and its physiological effects. Anyone who has seen a car illuminated by the shaded lamps, and particularly if this car has both shade and bare lamps that can be alternately burned, will not question the fact that there is a remarkable difference in the qualities of the light from the two arrangements. The glare from the bare-light sources is particularly disagreeable in street cars, and all-frosted bulbs can not do much to correct the fault. The car ceilings are low, and there is a vista along which the eye gazes. There are usually advertising cards to attract the attention toward the upper parts of the car, and there are unavoidable changes of intensity from car jarring and from voltage fluctuations that soon tire the muscles of the eye. Hence street railway lamps are being equipped with shades that protect the eyes of the passengers.

Every street railway must operate its lighting circuits and its power circuits as one. Hence at the very time when the lights are most needed the load on the system is the greatest, and the fluctuations of voltage are increased correspondingly. This trouble from voltage fluctuations was very apparent with the use of carbon-filament lamps, but it has become much less troublesome with tungsten lamps, since their candlepower does not change so rapidly at the different pressures.

At the meeting of the Chicago section of the Illuminating Engineering Society, November 12, 1913, Messrs. L. C. Porter and V. L. Staley presented a paper on "The Illuminating of Street Railway Cars." For car lighting, compared with carbon lamps, it was demonstrated that tungsten units produce better illumination at a saving in lighting expense. Where tungsten lamps are used it is desirable to install efficient reflecting devices, and in all cases a light interior car finishing is to be desired. The tungsten lamp for car lighting has reached a life of 2,000 hours in laboratory tests, and from 1,200 to 1,500 hours under service conditions. The strength of the lamp is such that it withstands surprisingly, bad operating conditions. It has practically superseded the tantalum lamp for car illumination.

The results of a study of car lighting made by Mr. G. H. Stickney, with the cooperation of Mr. E. W. Holst, of the Bay State Street Railway Co., were given. Two methods of placing the lighting units were tried, one being the use of a single row of fixtures down the center line of the car and known as center-deck lighting, while the other provides a double row of lighting units, one under each half-deck. There is little to choose between these two methods in efficiency, but the center-deck system is somewhat simpler and easier to install and maintain. With the center-deck system two circuits of 56-watt lamps, or one of 94-watt lamps, are used, and with the half-deck lighting 23-watt or 36-watt lamps are usually employed. It has been found that from 2.5 to 3 foot-candles are desirable on the reading plane of the passengers. This plane is considered to have an angle of 45° 3 feet above the floor. With either the center or half-deck lighting where efficient intensive-type reflectors are used, approximately 82 lumens per running foot of car body will supply this illumination. This corresponds to about 10 watts per running foot, or 1.25 watts per square foot of floor area.

Tests have shown that with the ordinary dark-yellow finish of street cars the efficiency of light utilization is approximately 15 per cent where no reflectors are used and 30 per cent with a good direct-reflector system. On one car where the finish of walls and ceiling was white, a utilization efficiency as high as 60 per cent was obtained. One pronounced advantage of the tungsten lamp over the carbon unit for car lighting is that the candlepower changes less on fluctuating voltages. The four tungsten lamps especially developed for railway service are rated at 23, 35, 56, and 94 watts, respectively. The efficiency of the two smaller sizes is 1.34 watts per candle, and of the two larger sizes 1.20 watts per candle. The ultimate saving justifies the rewiring of old cars to enable tungsten lamps and reflectors to be used.

One of the incidental features of street-car lighting is the outside illumination of platforms and signs, more particularly the latter. The largest single item in the cost of maintaining illuminated car-destination signs of the roller type is found in keeping the letters in legible condition. The custom is to retouch the letters by hand, but when necessary to renew a section of canvas and replace the names of the destinations by hand, painting is quite expensive. To reduce this cost of renewal to a minimum, Mr. G. W. Swint, master mechanic of the Nashville Railway & Light Co., Nashville, Tenn., has devised a scheme whereby a 36-name sign may be replaced with a new one at a cost of $1.50 for material and labor. Instead of doing the work by hand, the signs are printed on the canvas by wooden blocks of the hollow-letter type. The blocks were made in the company's shops, and as many prepared as there were destinations. The cost of carving the letters in the white-pine blocks was comparatively low, and their useful life is, of course, unlimited. The complete printing outfit comprises, in addition to the hollow-letter blocks, a section of plate glass by means of which a composition of printer's ink is evenly applied to an ordinary rubber roller, a padded table with clamps to hold the canvas firmly in position, and an old armature core which is used to press the wooden-block type against the cloth. The ink is applied to the block by passing the rubber roller across it, the block is then laid upon the white canvas, and the armature core is rolled once or twice across it.

The quality of printing ink applied to the hollow-lettered panels and the weight of the old armature core cause the ink to penetrate the canvas, giving a longer life than when applied by hand. The names making up a complete set of destinations are printed in series of five to a canvas panel. These panels are sewed together in long strips for the car signs. In case only a portion of this lettered canvas becomes badly soiled, it may be ripped from the rest of the roll and a new panel supplied. The work of printing these signs is so simple that an expert is not required, or even a man specially detailed to do the work. Two men familiar with the operation make eight five-name panels in an hour.

The Peoria (Ill.) Railway Co. has adopted route signs of a novel design on the city cars. To advise the public regarding a new system of car indications, a card map showing the various route lines of street railway drawn to an exaggerated scale, together with the sign indication applying to each, was pasted in each car. A facsimile copy of this card also was published in the daily papers for several weeks.

The sign is a triangular prism built of light structural angles and 18-gauge sheet metal, the base being shaped to fit the contour of the car roof. Two signs are mounted at right-hand diagonal corners of each car, and the right-angle faces of the signs are set parallel to the front and sides of the car. These two faces are 17 inches by 18 inches in size, and take a 12-inch initial letter and 3-inch letters in the printed destination. All letters are perforated with $\frac{5}{16}$-inch holes which permit reflected light from a single 16-candlepower lamp installed inside the sign to illuminate them at night. The interior of the sign is painted white to intensify the indirect letter illumnation, making it possible to read the names easily at 500 feet during either day or night. The lamps in the two signs are in series with the lamps in the car and are controlled by the same switches.

The lettered panels are interchangeable, as guides in the sign frame permit them to be removed and replaced by any other destination sign in case it it becomes necessary to change a car's routing. A complete equipment of sign panels is kept at each car house, and each crew is required to see that the correct indications are in place before the car is taken for a regular run.

These signs are useful not only to residents but to strangers, as they enable the destination of the car to be ascertained more easily.

SIGNALING AND DISPATCHING.

An increased amount of attention has been paid to the subjects of signaling and dispatching on electric railways, including the use of automatic stops, or such devices as the dictaphone; while even the "telegraphone," with its fine running wire to receive magnetically the record of vocal orders, has been under serious consideration in large electric railway systems in cities for "load dispatching" purposes, where it is desirable to know just what instructions have been given from one power plant to another. The main thing, of course, is the control of train movement or the automatic stopping of trains otherwise out of control.

The year 1912 saw a noteworthy development in block signaling, the main features of which may be briefly noted. The problem ceased to be one of the practicability of such a method, and became instead that of the selection and standardization of apparatus. Thus, for example, while the standardization of apparatus unquestionably reduces costs, the necessity for uniform signal "aspects" is actually of greater importance, especially as uniformity in this respect can be accomplished with greater ease when the installation of automatic signals on electric railways is only just beginning than at some later time when large and important roads are fully equipped with widely different types. This necessity is shown in cases where, through operating agreements, several interurban roads are using the same tracks. Each road may be using a special signal "aspect" on its own track so that motormen are hampered by the fact that they have to think in totally different terms at different portions of the route. In consequence of this demand for standardization, the upper left-hand quadrant, three-position arrangement for semaphores has already been approved by the electric railway associations.

The year 1912 was characterized by a remarkable growth of opinion in favor of light signals in which the semaphore arm, practically standard upon steam railroads, was replaced by colored lenses so illuminated as to be visible even in the brightest sunlight. A number of such installations were made during the year, and although the semaphore arm still appears to be considered as the most reliable indication from the standpoint of arrestive effect, the decreased first cost of the light signal, estimated to be in some cases as much as 30 per cent lower than the semaphore, together with the decreased maintenance due to the absence of moving parts, is a good indication that it will be subject to a still wider adoption during the next few years.

Of the different methods of control for signals, the continuous track circuit has maintained its leading position among installations on high-speed lines. This may be due partly to conservatism in following a method so universally used by the steam railroads, although one of the advantages claimed for it, namely, that it indicates broken rails, can hardly be said to apply with much force to electric railways. It has, however, a similar advantage in that it indicates defective bonding by the failure of the signals to clear. The thoroughly demonstrated reliability of the track circuit through many years of experience naturally can not be denied, and it was undoubtedly this feature which influenced the joint committee on block signals of the engineering and transportation and traffic associations at the Chicago convention in 1912 in recommending for high-speed interurban service the use of continuous track-circuit control. The fact that this recommendation was not accepted by the association in convention was indicative of the desire of the delegates to be left free either to accept new devices or else to await the development of systems not sufficiently tried out.

Much attention has been paid to dispatchers' systems, although the number of such installations is hardly comparable with that of the older track-circuit types. On the Piedmont Traction Co.'s lines a selector system controlling semaphore blades has been installed to enable the dispatcher to stop trains for orders which are transmitted by a telephone box attached to each signal mast. The Indianapolis & Cincinnati Traction Co. installed, as the other extreme, an exceedingly complete type in which connection between the dispatcher and the train is made at short sections of third-rail through a shoe on the car. By means of this connection the dispatcher can illuminate either a red or a green lamp in the cab of the train in accordance with his desire to stop the train or let it proceed, although an ingenious interlocking system prevents him from letting two trains proceed against each other.

Various forms of the trolley-contact system have been installed on a number of railways. Their greatly reduced cost offers a strong incentive to installation. In addition, the possibility of introducing a car-counting device by giving the contactor a directional sense makes this system of unusual advantage where permissive signals, allowing cars to follow one another into the same block, are desired. Permissive blocking, however, except for very low speeds, seems to have been regarded with decreasing favor.

As to automatic stops, on the Illinois Traction System a device has been developed by which the air brakes are applied in case a car runs past a home signal set at stop. Such a device is of undoubted value. On the New York, Westchester & Boston Railway the future necessity for automatic stops was considered to be such a certainty that the signal system was laid out in a manner which will permit them to be installed at any time, the overlaps to be effected by the interpolation of additional signals where necessary along the line.

Important legislative action in regard to block signaling developed through an enactment of the general assembly of Indiana. This law became effective on January 1, 1912, and placed with the state railroad commission power to compel the introduction of approved block signals on the railways of Indiana which had sufficient traffic or were surrounded by such conditions as to make block signals necessary. The results of this action seem to have been satisfactory. A very marked increase in mileage of interurban lines protected by signals resulted during the year. It is estimated that 18 per cent of the total electric railway mileage was being equipped, and that all lines coming within the scope of the enactment would be equipped within three years.

Of the large single-track installations made during the year, that of the Washington, Baltimore &

Annapolis Railroad is probably the most interesting. On this road the customary preliminary sections are omitted and each block is made self-contained, extending the full distance between sidings. Light signals set about 1,000 feet inside of the home semaphores take the place of the preliminaries, and all home signals are approached under control. The home signals at each end of the block are controlled by the whole block, but the light signals are controlled only by two-thirds of the block length at the opposite end. As each block is a unit, the movements of a car in one block do not affect those in the next one, and cars need be spaced no more than one block apart. In case two opposing trains pass home-semaphore signals at the same time, they will be stopped by the light signals, which will not clear until one train has backed out of the block.

The attention given to this subject is further emphasized in the report at the annual meeting of the American Electric Railway Association at Atlantic City, N. J., October, 1913. The report stated that during the year the majority of the new installations of block signals on high-speed interurban lines were controlled through continuous track circuits. In view of this fact the committee repeated its recommendation of the previous year, that for high-speed interurban service automatic signals be controlled by the use of continuous track circuits, and that expenditures be concentrated on continuous track circuit control with a cheaper form of indication in preference to a more expensive form of signal and a less reliable control.

For signaling single-track suburban railways with headways between 5 minutes and 30 minutes and speed not exceeding 20 miles per hour, several schemes for trolley-contact signals were submitted, together with drawings of diagrammatic arrangements, according to different arrangements of passing sidings. It has been generally conceded that trolley-contact signaling is well adapted for this type of line. Track-circuit control for this general scheme of signaling has been installed, however, and may be used, possibly with certain limitations. For signaling double-track suburban railways with headways between 1 minute and 10 minutes and speeds not exceeding 30 miles per hour, several schemes for trolley-contact and track-circuit signaling were submitted, including both three-position and two-position signals. All these provide, either by overlaps or by distant signals, means for protecting the rear of a train which may be stopped a short distance beyond any home signal, so that it will not be hit by a following train which overruns the signal in making a stop.

For signaling single-track interurban railways with hourly headway and with speeds from 40 miles per hour to 60 miles per hour, two schemes were submitted. In one of these no track-circuit preliminaries are used, intermediate signals replacing the preliminaries. In the other the track-circuit preliminary is used with a light indicator, if desired, at the beginning of the preliminary, so as to indicate, to a car approaching the siding from the side on which the preliminary is located, the position of the home signal at the siding before it is reached. In both schemes absolute blocking from siding to siding is employed, either semaphores or light signals, or a combination of them, being used.

For signaling single-track interurban railways with 15-minute headways, trains in several sections and speeds from 40 miles per hour to 60 miles per hour, three schemes were submitted. One provides intermediate signals in place of preliminaries, and uses two-position signals, giving absolute blocking for following cars at one-half the distance between sidings. The second provides signals to be of the three-position type, following cars being blocked practically one-half the distance between sidings for following movements and from siding to siding for opposing movements. With this arrangement, both the stop and caution indications are given. With the third arrangement, cars are allowed to follow one another into an occupied block under a permissive indication, the blocking of opposing cars being absolute. Signals in one direction are normally clear, in the other normally danger. A light indicator is used at the beginning of the preliminary section, and a secondary light is used on the signal to provide the permissive feature. Light signals may be used if desired.

For signaling high-speed double-track interurban railways with 5-minute headway, only one scheme was suggested. With this arrangement, semaphore signals operating in three positions are used, the distance between signals being governed by the headway and speed. The operation is the same in either direction. Light signals may be used if desired. Stop and caution signals are displayed behind each car, and cars are able to follow each other as close as the distance between two adjoining signals, the second car in this case running under the caution indication continuously. Continuous track circuits are used with this scheme.

The committee recommended for adoption as standard the following aspects for trolley contact signals:

For a noncar-counting signal for single track, a single red light indicates "Stop: Do not pass contactor." A single green light indicates "Proceed by contactor to operate signal." If green aspect changes to red over yellow on passing contactor, it indicates "Proceed." If red and yellow are displayed on approaching signal, do not pass contactor until this aspect changes to green.

For a car-counting signal for single track, a single red light indicates "Stop: Do not pass contactor." A single green light indicates "Proceed by contactor to operate signal." If green aspect changes to red with a yellow light diagonally below on passing contactor, it indicates "Proceed." But if yellow light changes to opposite side of red, "Proceed under control into block, as block is occupied by car running in same direction as car about to pass under contactor."

It is to be understood that red with staggered yellow on either side indicates "Block occupied with same direction of traffic," and that this permits proceeding past contact device only in case staggered yellow changes from one side to the other, which indicates the recording of the car. Changing from one yellow to the other permits proceeding under control.

For light aspects for car-spacing signals operated by trolley contactors or other forms of end-set device used for double track, a single red light with a white telltale light indicates "Stop." A single green light with no telltale light indicates "Proceed." A single yellow light with no telltale light indicates "Proceed; next signal at stop." For two-position signaling the latter indication is omitted. The aspect called the telltale indicates that the contactor has operated the signals, and in practice it should be located on the next pole beyond the signal.

The report of this committee included an interesting appendix in regard to automatic stops for electric railways, a subject which, owing to accidents of a serious character on steam lines, has received considerable attention. Any historical data concerning the automatic train stop and its development should refer to the system which has been in successful operation on the lines of the Boston Elevated Railway for more than 12 years. This was a modification of an overhead-contact type of automatic stop, providing for the operation by the signal of a rocker shaft lying transversely to the track and equipped with a tripper arm which moved into and out of the path of an arm suspended from the forward end of the car. To this arm on the car was attached a valve which vented the train pipe when operated by the track tripper arm in the event of a train overrunning the signal in the stop position.

In 1903 this system in modified form was introduced on the lines of the Interborough Rapid Transit Co. of New York City, and later on the Philadelphia Rapid Transit System. The modification was of minor importance, however, consisting merely in the operation of the rocker shaft by a pneumatic cylinder separate from the one which operated the signal. The valves of the two cylinders were jointly controlled by the track-circuit relays of the block system.

A few years ago the same system was introduced on the lines of the Hudson & Manhattan Railroad, which were then all in tunnels, and on those of the tunnel and terminal division of the Pennsylvania Railroad across New York City and under the North and East Rivers. In its application to the Pennsylvania tunnels, it was found necessary to meet a condition not previously encountered. Trains ran beyond the tunnels into open country and through towns and across highways where high speeds were permissible. Under these conditions the brakes might be set by contact of the lever of the automatic train-stop valve with loose objects or with snow and ice, and a modified form of tripper arm was developed to overcome this difficulty. The valve is of the plunger type and is mounted between two guards, one in front and one in the rear of the plunger, so that it is protected against operation by any force not acting vertically upward against it.

The use of automatic signals on regular trolley city lines may be noted. The Easton Transit Co. has an important block of single track in Easton, Pa., on Walnut Street, from Northampton to Washington, between Sixth and Ninth Streets. The length of the block is 2,250 feet; running time, about 2½ minutes. The greater part is on a grade a little less than 5 per cent downward toward Northampton Street. About one-third of the distance from Northampton Street there is a branch leading off the single track to Ferry Street, used only by one interurban line. The block is traversed by four lines of cars, each, however, only in one direction: The South Bethlehem Interurban, hourly, eastward only; the Bethlehem Interurban, hourly, westward only (from Northampton Street to Ferry Street); two local lines, namely, Walnut Street and College Hill, 10 minutes' headway, westward only; South Side belt line, 10 minutes' headway, eastward only; thus making 14 cars per hour passing through the block, and amounting to some 280 regular cars per day. During the season 24 cars on the Island Park line return through this block between the hours of 10 and 12 p. m.

Signals have been installed to facilitate movements on this block, superseding the hand signals hitherto used. The signals are controlled through trolley contactors placed two spans in advance of the signal aspect at each end of the block. An additional contactor is placed on the curve from Walnut to Ferry Street connected to clear the signals only, and wired to signal 2. The operation is as follows: The signals are normally neutral, and show no lights or disks. A Walnut Street local, for instance, going up the hill, running under contactor *a*, sets signal 1 at stop, a red light and red disk, thereby preventing an opposing movement down Walnut Street, and signal 2 responds by showing a permissive signal, a white light and white disk. When the car leaves the block under contactor *d* (Washington Street), both signals are restored to the normal neutral. Should, however, a Bethlehem Interurban follow the local, then the signals would not change until the local had passed under contactor *d* and the Interurban had passed under contactor *e*, thus leaving the block clear. In fact, a number of cars might follow into the block in succession, and the signals would not change until the last had left. Similarly, an Interurban returning from Bethlehem, running under contactor *c*, will set signal 2 at stop and signal 1 at permissive, and will clear both signals in leaving the block under contactor *b*. Thus the signals give absolute protection against any opposing movement but permit following movements to be made, warning the motorman, however, that the block is occupied. Any possible shifting movements around the terminals of the block are taken care of by the signals automatically. The signals are kept in the neutral or clear position by power from the trolley line, and the car entering the block opens this normally closed circuit through a revolving or step-by-step switch in the relay, permitting the distant signal to go to the stop position. The movement of the red disk to the indicating position closes a return or answer-back circuit over another line to give the permissive signal to a following car. Thus the stop signal must first be given before the permissive can be displayed, and therein lies its fundamental safety. Failure of power in the trolley line will set all signals at stop.

No batteries are required, nor is the track modified in any way, the signals being lighted and operated by taps from the trolley. The trolley contactors are flexible strips which are wiped by the trolley wheel, which thus makes the contact. The signal box is supported on a convenient iron bracket, the upper part containing the lights and disks, and the lower the oil-immersed relay, or intermediate apparatus for changing the transient current impulses that the car makes in running under the contactor into signal indications.

The Southwest Missouri Railroad operates 75 miles of track, about one-third of which is double track. Cars are run at from 3 to 30 minutes' headway, but the lines upon which service more frequent than 30 minutes is given are double-tracked. For the past 20 years the dispatching of cars on this road has been by telephone, none of the orders being reduced to writing. More recently, however, a new feature was added to the telephonic system by the installation of a dictaphone in the dispatcher's room, with the effect that since then every order given to trainmen by telephone has been duly recorded on the dictaphone and can be reproduced in case of any dispute or misunderstanding. These records are preserved for a period of three days, when they are scraped and the blanks are put back into service. The system is described as highly satisfactory. So far as known, the dictaphone in the company's office in Webb City, Mo., is the first one used in train-dispatching work.

Telephone dispatching.—The use of the telephone in train or car dispatching has become so general a thing as to excite no comment. Some of the installations are quite extensive. A typical case is the equipment of the Oregon Electric Railway in 1913. This railway is an integral part of the great system of railways which reaches from the North Pacific coast to the Great Lakes and the Missouri and Mississippi Valleys, comprising the North Bank Road, the Oregon Trunk, Great Northern, and Northern Pacific Railways, and the Burlington Route. The Oregon Electric line operates from Portland to Eugene, Oreg., and from Portland to Forest Grove, Oreg. The former division traverses the heart of the famous Willamette Valley, which is one of the richest and most productive agricultural portions of Oregon.

The telephone train-dispatching system covers these two divisions. The former is approximately 40 miles while the other is approximately 125 miles in length. There are two train dispatchers, both located at the Hoyt Street Station, Portland.

The apparatus includes two complete dispatcher's equipments comprising key cabinets and 45 calling keys in all besides the telephone sets; and trains are equipped with portable telephone sets for use in communicating with headquarters from points between way stations. Each portable set is furnished with line poles and plugs. The latter are used in connection with 50 type jacks installed at the various sidings along the right of way.

AIR-BRAKE EQUIPMENT.

The extent to which this class of apparatus has increased is shown by the tables in the report, which emphasize the tendency exhibited in the data for 1907. The conditions governing are brought out in an interesting manner in the action of the New York supreme court, appellate division, of July 10, 1913, sustaining the public-service commission of the first district in ordering all passenger cars within New York City that weighed more than 25,100 pounds to be equipped with air brakes. This would appear to be conclusive in many ways, but the review [1] of the evidence and tests by Mr. J. N. Dodd, engineer of the commission, is not accepted by the engineer in charge of the tests for one of the companies most directly affected, who says: "He has carefully eliminated every particle of data that bore in favor of the hand brakes, such as the wet-rail or bad-rail tests, and the reversal stops, and has regarded as available only that which tended to prove his previously determined position. He has also absolutely ignored a great mass of other tests, several hundred in number, the results of every one of which were adverse to his position."

In the course of his discussion of the subject, Mr. Dodd remarks that at first glance it seemed reasonable to suppose that exhaustive tests had been made by some authority to determine the maximum weight of cars which might be operated safely with hand brakes. A long search, however, failed to reveal any such series of tests. When comparative tests had been made by any company or other authority, most of the cars tested had been of the same weight. No thorough, exhaustive test apparently had been made for the purpose of determining the limiting weight of cars which might be safely operated with hand brakes. Moreover, when available records of various tests were examined, they were found to be contradictory and inconsistent. For example, the tests by the New York railroad commission in 1899 on cars weighing about 20,000

[1] Electric Railway Journal, Sept. 13, 1913.

pounds showed hand brakes better than air brakes at almost all speeds. On the other hand, tests on the Hanover Street railways, reported to the International Street and Interurban Railway Congress, Munich, 1908, on cars of about the same weight showed air brakes far superior at all speeds.

In the course of this search it became apparent that tests do not always furnish a reliable criterion of the relative value of different brakes. They merely state the stopping distance of the car under the particular conditions that obtained at the time of the test. Among these conditions may be mentioned the brake-shoe adjustment, the weight of the car, the condition of the rail, and the human element. Most of these factors vary widely during the course of the day, and each of them may change independently of any of the others. Thus, on account of the wear of the brake shoes, the brake adjustment may change materially even in the course of a single trip. The weight of the car is continually changing, owing to the fluctuations in the number of passengers. The condition of the rail may alter entirely in the course of a few seconds. This change is often such that a visual inspection of the rail fails to reveal its quality. Thus a wet rail may provide an ideal surface for stopping a car quickly, or it may offer the reverse. In the same way, though not to the same extent, the distance in which a car may be stopped on a dry rail varies according to whether the rail is clean or covered with dust or dirt. For this reason it is impossible to be sure that the rail conditions are the same in tests on two different brakes, or that the rail condition at the time of the test represent correctly average rail conditions under which the car must operate throughout the year.

The human element also is extremely variable. In actual service there are many strong motormen, and many who are physically weak; many who are intelligent and mentally alert, and many the reverse; many in fresh physical and mental condition, and many tired from a day's work.

During most tests the motorman usually knows that he is soon to receive the stopping signal and, knowing what he is expected to do, is intent upon doing that thing in the most efficient manner. During such tests, also, the streets are usually bare of traffic, and the motorman's attention is not distracted by other duties, such as making up lost time, keeping a lookout to pick up passengers, and obeying the conductor's signals. Usually a picked motorman is chosen, selected for his general intelligence and interest in his work. The motorman is generally in fresh physical condition, and therefore in good mental condition and to that extent capable of responding to any demands made upon him. The results obtained in service at the close of a long, wearying day's work would be entirely different from the results obtained in any series of tests. It is impossible to devise any series of tests under conditions which even approximate the average conditions existing in actual service because it is impossible to tell what the average of these varying factors may be. Hence it is not wise to place too great reliance upon tests as a method of determining the type of brake which must be used on any type of car.

The census reports for 1902 and 1907 give the following figures relating to cars for city service:

	Cars, total number.	Number equipped with air brakes.	Per cent equipped with air brakes.
1907	83,641	31,684	37.8
1902	66,784	7,905	11.8
Increase	16,857	23,779	

According to these figures, practically all new cars purchased during this period were equipped with air brakes, and many of the old cars had air brakes added. On the other hand, although these figures show the growing esteem in which the air brake is held throughout the country, they give no indication of the weight of cars so equipped.

More definite information is obtained from a study of the braking practice observed in various cities. It appears that all cars are operated with power brakes in the cities of Cleveland, Detroit, Los Angeles, Milwaukee, Minneapolis, St. Paul, and St. Louis. In addition, all double-truck cars are equipped with power brakes in Chicago, Cincinnati, Indianapolis, Louisville, Omaha, and Seattle, and in the state of New Hampshire. In the city of Denver all new cars purchased are equipped with air brakes and practically all the old ones are so equipped. This evidence is important as showing the opinion on this subject held by managers and municipal authorities throughout the country.

The New York law requires all street railroad companies under jurisdiction of the public-service commissions to report all accidents which occur on their lines. A study was made of these accidents in the first district by the commission of that district to determine what evidence could be obtained from them bearing on the subject of brake equipment.

From the accidents so reported for the years 1909 and 1910, all those caused by the front end of a moving car were selected. These accidents were listed according to the weight of the car. By the use of the average number of cars of each weight operated throughout the year, the figure representing the total number of such accidents listed under each weight of car was reduced to the number of accidents per 100 cars.

The maximum weight of single-truck cars is about 20,000 pounds. The weight of double-truck hand-brake cars used in New York City in 1909 and 1910 varied from 20,000 pounds to about 40,000 pounds. The weight of air-brake cars varies from about 25,000 pounds to about 50,000 pounds. The list of accidents reported for the various weights of cars is given in the following table:

ACCIDENTS TO SURFACE CARS REPORTED TO PUBLIC SERVICE COMMISSION, FIRST DISTRICT, DURING 1910 AND 1909.

	Total.	1910	1909	Average per year.
Hand-brake single-truck cars, weight 16,000–20,000 pounds:				
Number of accidents	166	111	55	83
Number of cars	820	765	875	820
Accidents per 100 cars	20.2	14.5	6.3	10.1
Hand-brake double-truck cars, weight 20,100–25,000 pounds:				
Number of accidents	62	42	20	31
Number of cars	281	281	281	281
Accidents per 100 cars	22	15	7.1	11
Hand-brake double-truck cars, weight 25,100–40,000 pounds:				
Number of accidents	651	412	239	326
Number of cars	2,010	2,001	2,018	2,010
Accidents per 100 cars	32.4	20.6	11.9	16.2
Air-brake double-truck cars, weight 25,000–40,000 pounds:				
Number of accidents	212	162	50	106
Number of cars	841	959	723	841
Accidents per 100 cars	25.2	16.9	6.9	12.6
Air-brake double-truck cars, weight 40,000 pounds and up:				
Number of accidents	187	94	93	94
Number of cars	699	704	695	699
Accidents per 100 cars	26.8	13.3	13.4	13.4

The value of such a list lies in great part in the fact that it deals with large numbers. A large number of cars will usually be operated under average conditions. A small number of cars may be and often are operated under special conditions. For example, a small number of cars may be operated in a very congested territory or the reverse, or the daily mileage may be exceptionally large or small. Such criticisms do not usually hold when large numbers are dealt with.

The figures given in the above table suggest the following conclusions:

1. On single-truck cars weighing not more than 20,000 pounds, hand brakes are satisfactory, and no improvement could be obtained by the use of air brakes.

2. On double-truck cars weighing not more than 25,000 pounds the evidence is inconclusive. Although the number of accidents per 100 cars is small, the number of cars is small, so that the record lacks weight.

3. Cars weighing from 25,000 pounds to 40,000 pounds equipped with hand brakes were involved in about 30 per cent more accidents than were an equal number of cars of the same weight equipped with air brakes.

An examination was also made of the number of accidents reported on cars weighing from 25,000 pounds to 30,000 pounds. In this class there were a great many cars, and the record showed even more strongly in favor of air brakes than did the record of the larger class, including cars weighing from 25,000 pounds to 40,000 pounds.

Mr. Dodd held that a more accurate criterion would have been a comparison on a mileage basis—that is, a record of the accidents, say, per 1,000 miles. Air-brake cars, being newer, are more popular with the traveling public than are hand-brake cars. With the same motor equipment the schedule speed of an air-brake car is higher than that of a hand-brake car. Air-brake cars are in much greater favor with the motormen because of their ease of operation. The power consumption of air-brake cars is considerably less than that of hand-brake cars on account of the fact that with hand-brake cars motormen usually operate in congested traffic with the brake partially applied so as to be able to stop the car quickly when necessary, while with the air brake they run free. For all these reasons it appears probable that for cars of the same weight the mileage of cars equipped with air brakes is much greater than that of an equal number equipped with hand brakes. It therefore follows that a record of accidents on a mileage basis would be much more favorable to air brakes than the record given above.

The recommendations of the presiding commissioner were as follows:

1. That all double-truck passenger surface cars in service weighing over 27,000 pounds should be equipped with power brakes and geared hand brakes on or before June 1, 1912. This will give the companies an opportunity during the next six months to equip with power brakes all of their open cars weighing 27,000 pounds and upward, and also their closed cars during the summer of 1912 which will be required to go into service in the autumn.

2. That all double-truck passenger surface cars in service weighing over 25,100 pounds should be equipped with power brakes and geared hand brakes on or before June 1, 1913.

3. That all double-truck passenger cars weighing 25,100 pounds or less should be equipped with geared hand brakes on or before June 1, 1912.

4. That all cars other than passenger cars should be equipped with power brakes and geared hand brakes on or before June 1, 1912.

One of the companies most directly affected by the order had 1,125 cars on which both air brakes and geared hand brakes would have to be provided, and the total cost of the change was estimated at $560,000. It secured a rehearing and conducted a series of tests on the relative stopping distances that could be obtained with air brakes and various makes of hand brakes. The series included tests of five different makes of hand and air brakes adjusted to four different ratios or pressures, tests on three different weights of cars, tests on wet and on dry rail, and tests with and without sand. In most cases the car was stopped by means of the brake and also by reversing the motors. With the air brake the car was stopped by the "service" application and by the "emergency" application. Tests were made on an empty car, on a car loaded with sand to represent a seated load, and on a car loaded to represent a standing load. The car was stopped when running at 5, 10, 15, and 20 miles per hour. Three stops were made at each speed and load, making 36 stops for each complete test of each brake and method of braking.

From these tests an enormous number of data were obtained. "For the sake of simplicity," Mr. Dodd claims, "it was necessary to eliminate from consideration as many as were not essential or for any reason not reliable."

The wet-rail tests were very erratic. In many instances the stops were much longer than the corresponding stops made on the dry rail, and also in many instances they were much shorter. Two consecutive stops, made apparently under identical conditions, would vary from each other in a ratio sometimes as high as four to one. Although operation under bad rail conditions is very important, the results of these wet-rail tests were such that no consistent conclusions could be obtained from them, and they were for that reason disregarded.

The motor-reverse stops were disregarded, for many reasons. In the motor-reverse tests the stop was obtained principally by the motor. It was not a test of the brake. Such a method of braking requires an entirely different procedure in an emergency from that employed in ordinary "service" braking. Consequently, it is probable that the results obtained in these tests by this means of braking were superior to what would be obtained in actual operation, inasmuch as in the tests the motorman knew in advance that he was to stop the car in a certain manner. It also appeared that although reversing the motors often gave better results than stopping by means of the brake, this was the case, as a rule, only at low speeds. At high speeds reverse stops usually gave poorer results than brake stops, and at these speeds the superiority of the brake stops was much more marked than the superiority of the motor stops at low speeds. For these reasons the reverse stops were eliminated from consideration and attention was devoted to the brake stops.

For the purposes of the hearing, the object of the tests was to determine what brake would stop a car in the shortest distance in order to avoid an accident. For this reason the "service" stop was not considered, the brakes being considered solely on an "emergency" basis.

Since the purpose of the tests was to determine the action of the brake in its operation throughout the year, individual stops were disregarded and the average length of stops was the only figure considered.

Summing up his conclusions on the data and tables set forth, Mr. Dodd asserts that to the extent that the tests were reliable as evidence they proved: First, that air brakes properly adjusted are superior to any hand brake tested; second, that in actual service the strain produced in the brake rigging by an air brake is much less than that caused by those hand brakes which showed themselves most efficient; third, that in an emergency the possibility of skidding is much greater with a hand brake than with an air brake, and that, therefore, the results obtained in actual service with a hand brake would be inferior to those obtained with an air brake. The result of the tests, therefore, was to confirm the commission in its previous opinion. In the final order on the motion, made June 21, 1912, section 4 of the order, relative to service cars, was rescinded and increased time was given to the companies to comply with the other sections, but no change was made in the weights affected.

A curious example of the onerous obligations that may be thrown on street railway companies at any time in the operation of their mechanical departments is afforded by the air-brake law passed by the legislature of Ohio in 1910, requiring all electric cars to be equipped with air brakes of a certain type. The brake defined was one which would be capable of applying to all the brakeshoes and wheels of an electric car a maximum permissible braking pressure and of automatically reducing such braking pressure as the speed of the car decreased. Under the law, 50 per cent of all electric cars in Ohio had to be so equipped prior to January 1, 1911, and 75 per cent prior to January 1, 1912. The law provided a penalty of $100 for each violation of the act, the penalty to be recovered in a suit to be brought by the prosecuting attorney of the county where such violation occurred. Moving under this act, the prosecuting attorney of Jefferson County, Ohio, brought suit against the Tri-State Railway & Electric Co. and the Steubenville & East Liverpool Railway & Light Co. in the court of common pleas, No. 2, of Jefferson County, before Judge Shotwell. The defense was that there was no brake such as the public-service commission of Ohio would approve, and that there was no air or electric brake or apparatus capable of applying to all the brakeshoes and wheels of cars a maximum permissible braking pressure and of automatically reducing this pressure as the speed of the car decreased.

In his opinion Judge Shotwell stated that the statute was evidently passed with the idea of requiring the equipment of cars with a patented brake. Among the witnesses at the trial was the patentee. Testimony was brought out that a car equipped with his brake had been in use in Dayton while the bill was under consideration by the legislature. He had sold his interest in the patent to a company in Indianapolis, but acknowledged that the brake was not being manufactured. The factory where the brake had been made was devoted to repair work in other branches of mechanical engineering. For a number of years he had made no further effort to develop the brake. As a result, the court declared that there could be no dispute that such a brake was not on the market, that nobody was making it or selling it, and that no one could buy it.

One of the witnesses for the defense, Mr. Thomas Elliott, chief engineer, Cincinnati Traction Co., said that he had made an examination of the brake and considered it worthless for the purpose of attaining the result claimed. Mr. R. N. Henning, superintendent of motive power, Indiana Union Traction Co., testified that the brake was a failure and would not operate.

Witnesses for the plaintiff consisted of a conductor and a motorman on one of the local lines, who said that they had seen a brake of the kind in Chester, W. Va., but on further examination acknowledged that they knew nothing about the technical construction of brakes and did not know whether such a brake could be used on the East Liverpool lines. The existence of such a brake at Chester was denied by witnesses for the defendant.

Another witness was formerly the member of the state legislature who had introduced the bill. He testified that by trade he was a decorative painter and that he had no special knowledge of railway operation or the construction of brakes. He said that during the session of the legislature in 1910 he had met the patentee, had adopted his ideas in regard to the practicability of the brake, and had embodied them in the bill introduced by him in the legislature.

The court then carefully reviewed the legal situation which occurs when a legislature passes a statute which can not be enforced, and, after quoting various precedents, concluded that the law must be considered to be inoperative. Hence there was a finding in favor of the defendant.

ELECTRIFICATION OF MAIN LINES.

The progress made in the electrification of main lines of steam railroads during the last five-year period is quite notable. The data as to conditions existing in 1912–13 and to be worked out in 1914 have been compiled in a very helpful manner by Mr. E. P. Burch, of Minneapolis. The table given herewith, as will be seen, is based on a group of 10 roads in regard to each class of work.

NAME OF RAILROAD.	Miles of road.	Miles of track.	Number of locomotives.	Explanation, or name of division.
Principal main-line electrifications in service:				
New York, New Haven & Hartford	88	500	100	New York to New Haven and switching yards.
Spokane & Inland Empire	168	187	12	Main line; excludes local lines.
Butte, Anaconda & Pacific	27	90	17	Largely mine switching.
French Southern	165	205	16	Partly equipped.
Baden State	10	31	34	Basel-Säckingen.
Prussian State	19	50	13	Dessau-Bitterfeld.
Italian State	104	156	84	Valtellina, Giovi, and Savonna lines.
St. Polten-Mariazell	63	68	14	
Ratische Mountain	46	48	11	
Bernese Alps	52	55	16	Lotschberg line.
Principal terminal or passenger-service electrifications in service:				
New York Central	50	240	47	Terminal service; no freight service.
Pennsylvania	15	72	35	Terminal service; no freight service.
Long Island	100	250	0	Motor-car trains only.
West Jersey & Seashore	75	150	0	Motor-car trains only.
New York, Westchester & Boston	19	63	0	Motor-car trains only.
Southern Pacific	50	100	0	Motor-car trains only, largely on Oakland streets.
Metropolitan Railway, London	35	70	20	Main line and suburban trains.
London, Brighton & South Coast	60	160	0	Motor-car trains only.
Paris-Orleans	14	46	11	Main line and suburban trains.
Hamburg-Ohlsdorf	17	41	0	Motor-car trains only.
Main-line electrifications to be completed in 1914 and 1915:				
Norfolk & Western	30	85	25	Bluefield-Vivian division.
Pennsylvania	20	90	0	Philadelphia suburban.
Canadian Pacific	30	43	4	Rossland-Castlegar grades.
Chicago, Milwaukee & Puget Sound	113	168	14	Rocky Mountain division.
North Eastern, England	18	44	10	Freight service.
Swiss Federal	93	100	20	Chiasso-Lucerne section of St. Gotthard division.
Swedish State	80	93	13	Kiruna-Riksgränsen division.
Prussian State	81	124	44	Lauban-Königszelt division.
Italian State	32	60	16	Milan-Lecco division.
Vienna-Pressburg	42	50	8	Main-line service.

Steam railroad electrification, in one sense, is almost as old as the electric railway itself,[1] for among the first lines to be electrified were the dummy roads in the suburbs of the larger cities and the shorter steam railroad branches which had become part of urban traction systems.

Baltimore & Ohio Railroad.—It is an interesting coincidence that the Baltimore & Ohio Railroad, which in 1828 placed in service the first American-built steam locomotive on its initial 3 miles out of Baltimore, should also have been the pioneer user of heavy electric locomotives. Its Belt Line tunnel at Baltimore, comprising 7.4 miles of single track, was electrified on the third-rail system in 1895 to eliminate ferriage and give the railroad direct entrance to Baltimore.

New York, New Haven & Hartford Railroad.—The New York, New Haven & Hartford Railroad, which holds the lead in length of electrified track, entered the electrification field in 1895, when it equipped with electric power for direct-current overhead operation a total of 16.8 miles of single track between Nantasket Beach and Pemberton, Mass., on a peninsula about 10 miles southeast of Boston. This line is operated with electricity only in summer.

The company's first heavy interurban electrification, and the first undertaken by any trunk line in the United States, was the equipment, in 1902, of its Providence-Warren-Bristol-Fall River branch with the 550-volt,

[1] Electric Railway Journal, June 7, 1913.

direct-current, simple overhead system. It is 38.5 miles in length, measured as single track, and consists of a double track from Providence to Warren, a single track from Warren to Bristol and Fall River, respectively, sidings at Providence, etc. The service is of standard interurban character and includes the handling of baggage. Electrification of this line made it possible to give a faster schedule despite an increase in the number of stops made by local trains.

During 1907 the New Haven company added to its branch electrifications the Middletown-Berlin-Meriden and Hartford-Vernon-Melrose lines in Connecticut. The construction on the Middletown-Berlin section, 10.4 miles long, and on the Middletown-Meriden section, 7.2 miles long, is of 600-volt, direct-current, plain overhead type. These sections were electrified to give more profitable feeders for the trunk lines and to build up the towns served by providing connections with the local street cars.

The Vernon and Melrose lines follow the tracks of the Hartford street railway system of the Connecticut company for 2.5 miles to East Burnside, where the cars are deflected to the steam railroad right of way from Buckland, Manchester, and Talcottville to Vernon Junction, a distance of about 16.8 miles, single track. At Vernon Junction the line swings to the north and passes to Rockville and Melrose over single-track branches totaling 14.7 miles in length. The electrification of these lines made it possible to bring passengers into the business section of Hartford and to improve the headway through the operation of single cars.

In addition to these direct-current electrifications, the New Haven company's tracks between Middletown and Cromwell, Tafts and Central Village, etc., carry trolley cars of its subsidiary, the Connecticut company, besides the regular steam service.

The 11,000-volt, single-phase, 25-cycle main-line electrification of the New York, New Haven & Hartford Railroad now in operation comprises 21.5 miles of route, or 109.3 miles of single track, between Woodlawn at the New York City line and Stamford; and the Harlem River branch has been completed with 63.4 miles of main line and 78 miles of yard track, a total of 141.4 miles of single track. The main-line electrification for the 41 miles between Stamford and New Haven now nearing completion will comprise 170 miles of main-line track and 40 miles of yards and sidings, or 210 miles in all. The board of directors has approved the electrification of the four-track main line between Providence and Boston, a distance of approximately 50 miles. This affects 196 miles of main-line track and 20 miles of yards and sidings, a total of 216 miles.

The company also operates a single-phase cross-country line of light catenary type between Stamford and New Canaan, comprising 7.7 miles of single track. This road carries electric passenger traffic and steam freight, the latter being handled at night.

On May 27, 1911, the Boston & Maine Railroad placed in service the Hoosac Tunnel, which had been electrified for 11,000 volts, 25 cycles, single phase, in conformity with the practice of the New York, New Haven & Hartford Railroad.

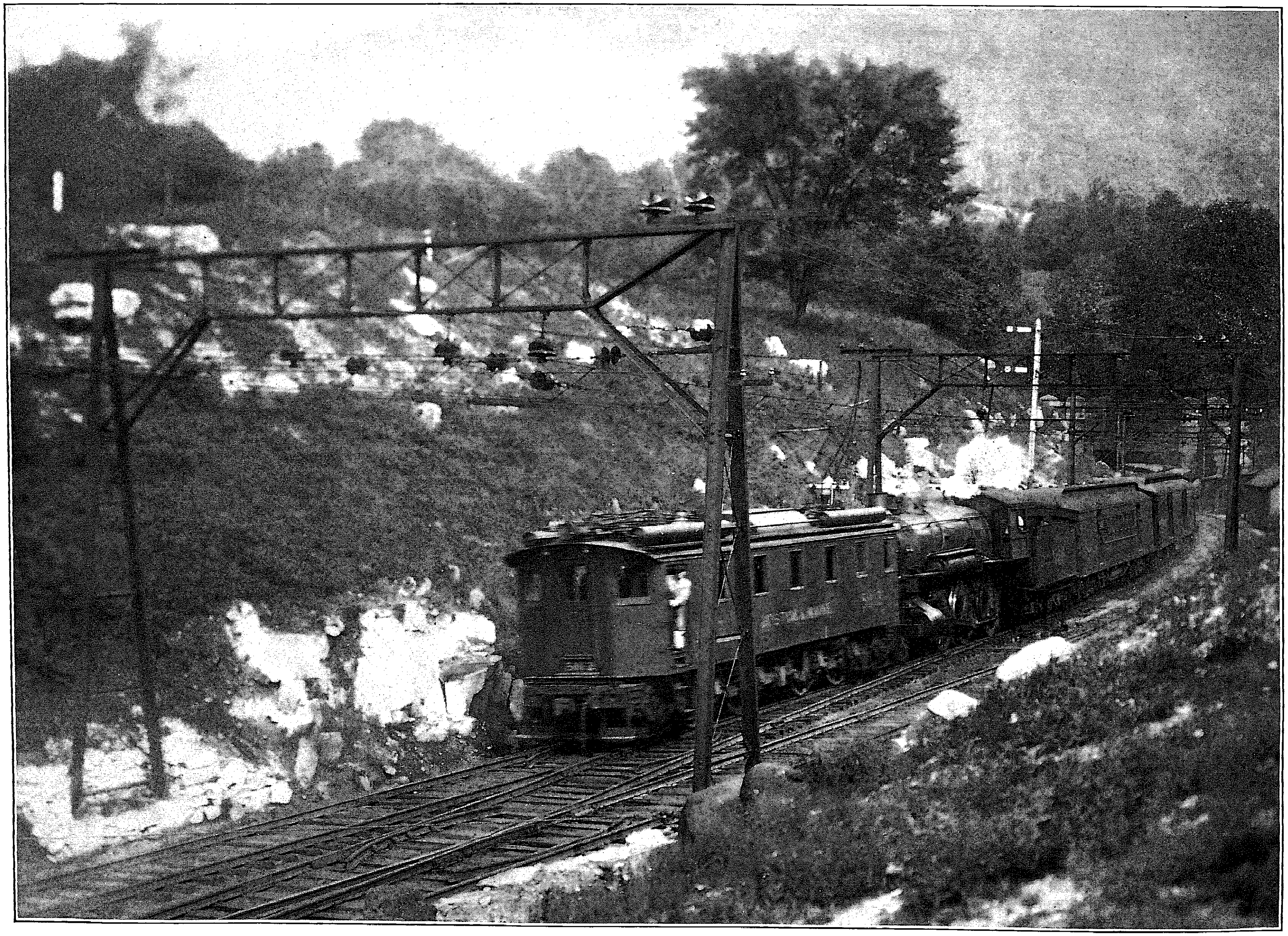
The New York Central and New Haven electrifications were accelerated by the compulsory conversion of the joint viaduct and tunnel entrance to the Grand Central Station via Park Avenue, New York. Unlike the alternating-current, direct-current electrification of the New Haven company, the New York Central equipment is direct-current, third-rail throughout. The latter electrification comprises two lines out of New York City—the Harlem division to North White Plains, 24.4 miles northeast, and the Hudson (main line) division to Harmon, 34 miles north of New York, a total of 234.4 miles of single track. The New York Central & Hudson River Railroad has no immediate plans for additional main line work, but a plan to electrify its freight entrance along the Hudson River in New York City is being considered by the railway company and a committee of the board of estimate and apportionment of New York.

The electrification of the Detroit River tunnel, 19.2 miles of single track, was completed in October, 1910, by the Michigan Central Railroad, a subsidiary of the New York Central & Hudson River Railroad. This is a 650-volt, direct-current, third-rail line.

The Oneida Railway is a 600-volt, direct-current, third-rail line, comprising 44 miles of route, or 118 miles of single track. It is an electrification of the main line of the West Shore Railroad between Utica and Syracuse, N. Y. The passenger cars operated by the Oneida Railway over this section also are run over the tracks of the Utica and Syracuse street railway systems, which, like the West Shore and Oneida companies, are controlled by the New York Central & Hudson River Railroad. The regular through steam service of the West Shore Railroad is still maintained over this section.

Electrification of the suburban lines of the Long Island Railroad, controlled by the Pennsylvania Railroad, was begun about 1903, the first electric trains being operated on the Atlantic Avenue division in July, 1905. The electrification was due to the reconstruction of this outlet from Brooklyn as a subway and elevated line, to the desire to encourage suburban and seashore travel, and to the necessity for greater terminal capacity in a section where property values were high. The conversion of all parts of the suburban system for third-rail, 600-volt operation has not yet been completed, but the electric lines now total 1,868 miles of single track.

During 1910 the Pennsylvania Railroad completed its New York terminal, comprising 98.4 miles of direct-



LINE CONSTRUCTION, HOOSAC TUNNEL ELECTRIFICATION, BOSTON & MAINE R. R.

(Face p. 402.)

current, third-rail construction from Manhattan transfer station opposite Newark to Long Island City, via a new route to Bergen Hill and through tunnels under the Hudson River, Manhattan Island, and East River. By arrangement made in 1911 with the Hudson & Manhattan Railroad, cars of the latter company are operated electrically over the right of way of the Pennsylvania Railroad between Newark and Jersey City.

The West Jersey and Seashore division of the Pennsylvania Railroad between Camden (opposite Philadelphia) and Atlantic City comprises 150.3 miles of 700-volt, direct-current, third-rail construction. This electrification was due chiefly to the desire to encourage seashore travel on high-speed trains. The electric service was opened September 18, 1906.

The route of the approved Philadelphia-Paoli electrification covers a distance of 20 miles. This line is to form the beginning of a general electrification of the Pennsylvania's lines in and around Philadelphia. The length of the electrification, measured as single track, will be approximately 90 miles, depending on the number of sidings converted.

In June, 1907, the Erie Railroad completed the electrification of its Mount Morris division between Rochester, Avon, Geneseo, and Mount Morris, N. Y., a route distance of 34 miles, equivalent to 40 miles of single track. This line, which is of interurban passenger character, is operated at 11,000 volts, 25 cycles, single phase, with Niagara power.

During 1911 the Southern Pacific Railroad converted 96 miles of suburban steam track in and about Oakland, Alameda, and Berkeley, Cal., to overhead 1,200-volt, direct-current operation.

The electrification of the Grand Trunk Railway, as carried out in 1908 under the name of the St. Clair Tunnel Co., comprises 4 miles of tunnel track at Port Huron, Mich., operated at 3,300 volts, 25 cycles, single phase.

The electrification of the Great Northern Railway's Cascade Tunnel, between Leavenworth and Skykomish, about 100 miles east of Seattle, was completed in July, 1909, for 3-phase, 25-cycle, 10,000-volt operation. This is the only 3-phase line in the United States. It has 6 miles of single track, including the approaches. The distance between Leavenworth and Skykomish, the terminals of the completed 3-phase electrification, is 57 miles. The line was electrified to eliminate smoke troubles and increase its capacity.

This company is also considering the electrification of a 530-mile line between New Rockford, N. Dak., and Lewistown, Mont., for which roadbed and other construction contracts have been awarded. In this case electrification is favored because of the poor coal and water conditions for locomotives.

The Chicago, Milwaukee & Puget Sound Railway has contracted for hydroelectric power to operate its line from Harlowton, Mont., to Avery, Idaho, a distance of nearly 440 miles. It is probable that a 2,400-volt direct-current system will be used. Avery is 2,495 feet, Harlowton 4,163 feet, and the intermediate town of Deer Lodge 4,520 feet, above sea level. The distance between Avery and Deer Lodge, the terminals of the proposed initial electrification, is 211.5 miles, and between Avery and Harlowton 439.3 miles, all single track.

The Denver, Rio Grande & Western Railway has decided to electrify one 114-mile mountain division. The distance between Helper and Soldier Summit, which are to be the terminals of the initial electrification, is 29 miles, and from Helper to Salt Lake City 114 miles. Helper is 5,840 feet, Soldier Summit 7,454 feet, and Salt Lake City 4,224 feet, above sea level.

The latest mountain electrification is that of the Norfolk & Western Railway for the heavy coal-carrying line between Vivian and Bluefield, W. Va., comprising 30 miles of route, or 75 miles of single track.

Butte, Anaconda & Pacific Railroad.—In view of the many features of importance pertaining to the electrification of this line, reference to some of the details will be of interest. The Butte, Anaconda & Pacific is credited with being the first steam road operating both freight and passenger service to electrify its lines purely for reasons of economy. The special factors, such as terminal and tunnel operation or rapid suburban service, which have been the determining considerations in a number of steam railway electrifications, were not present in this case. This is also the first line to use 2,400 volts direct current into the trolley. During the first seven months, the line made approximately 201,000 miles and hauled about 2,365,000 tons of ore. The steam locomotive crews easily acquired proficiency in handling the electric locomotives; in fact, two or three days' instruction from a competent electrical man was ordinarily sufficient. The change from steam to electricity was made without any change in the personnel of the train crews and without any delays or alterations in the schedule. The engineers, without exception, have expressed themselves as pleased with the easy operation of the locomotives. The locomotives have been maintained by the regular shop force with the assistance of one man experienced in electrical apparatus.

The Butte, Anaconda & Pacific is essentially an ore-hauling road, the freight traffic from this source originating at the copper mines located near the top of Butte Hill. From the mines, the ore trains are lowered down the mountain a distance of 4½ miles to the Rocker yards, a few miles west of the city of Butte. At this point, new main-line trains are made up for transportation to the smelters at Anaconda. The main-line division extends for a distance of about 20 miles through a rough mountainous country. At East Anaconda, the main-line trains are broken up and hauled up Smelter Hill to the stock bins, where each car is run over the scales and weighed. The east-bound traffic consists in returning empty cars to the mines and the transportation of copper ingot to the Butte yards, where it is shipped over other roads to refineries. The electrified lines extend from the Butte Hill yard to the smelter, a distance of 32 miles. There are numerous sidings, yards, and smelter tracks that have been equipped with overhead trolley, making a total of about 95 miles of single track.

Between the cities of Butte and Anaconda, which are located at the ends of the electrified portion of the system, there is considerable local traffic, both passenger and freight. The city of Butte and vicinity have a population of about 65,000 and Anaconda about 10,000. At Butte, the Butte, Anaconda & Pacific connects with the Great Northern, the Northern Pacific, and the Chicago, Milwaukee & St. Paul; and at Silver Bow, about 6 miles from the city, connection is made with the Oregon Short Line.

The maximum curve on the system is 20°, which occurs on the Butte Hill line. The locomotives are designed with sufficient flexibility to take a curve of 31° at slow speed. Four passenger trains each way per day are operated between Butte and Anaconda. Single locomotives are used, hauling trains of from three to five passenger and baggage cars.

The energy for the operation of the electric trains is purchased from the Great Falls Power Co., Great Falls, Mont. The power is stepped up to 102,000 volts for transmission to the transformer substation at Butte, a distance of 130 miles, over two separate parallel lines constructed on the same right of way. An extension of the system transmits power at 60,000 volts to a second transformer station at Anaconda, 26 miles farther on. The two existing substations at Butte and Anaconda were used to house the 2,400-volt motor-generator sets required for operating the electric trains, so that no additional buildings had to be constructed for this purpose. The energy is received by two 1,000-kilowatt, 3-unit motor-generator sets in each substation. These units operate continuously 24 hours per day, seven days in the week, to supply the necessary current for train operation. Each set consists of a 3-phase, 60-cycle, 1,450-kilovolt-ampere, synchronous motor operating at 720 revolutions per minute, direct-connected to two 500-kilowatt, 1,200-volt generators, insulated to operate in series for 2,400 volts. The generators are compound-wound and have both commutating poles and compensating pole face windings. They will carry three times the normal load for periods of five minutes, as well as the usual 50 per cent overload for two hours.

An automatic voltage regulator is used to maintain an approximately constant voltage at the terminals of the motor by power-factor regulation. The motors are protected against overload by inverse time-limit relays, which are set to open at four times the normal load. These relays have been adjusted to open under a sustained overload in about two seconds, and upon short circuit their action is practically instantaneous. Excitation for the generating units in each substation is obtained from two induction motor-driven sets, rated at 50 kilowatts each at 125 volts.

The 2,400-volt switchboards for controlling these sets are the first direct-current railway switchboards to be constructed for this high voltage. They are similar to the standard 600-volt types, but have increased insulation and special provisions for interrupting the 2,400-volt current. The circuit breakers and switches are arranged for remote control, and all the apparatus on the panels is provided with ample insulation to insure safety to operators. The 2,400-volt circuit breakers and switches are installed on separate panels above and back of the main panels, and are operated by connecting rods from handles mounted on the front of the main switchboard. The breakers are equipped with special magnetic blowouts and arc chutes, and provision is made for automatically inserting a high resistance in the generator field at the same instant the main circuit breakers open, thus reducing the generator voltage.

The overhead construction is designed for pantograph trolleys. The No. 0000 grooved copper trolley used over all tracks is supported by an 11-point catenary suspension from a stranded steel messenger cable. The hanger used on the straight-line construction is a rolled-steel strap looped over the messenger wire. The section breakers were designed for the 2,400-volt service, and at six points insulated crossings are necessary at the intersection of the 2,400-volt trolley with the 600-volt trolley of the city system. On the main line a very simple section insulator is used. This is made by paralleling the two trolley wires from the ends of the two sections at a suitable distance for insulation, so that the pantograph bridges the two circuits for a short distance, thus avoiding interruption of the power supply to the locomotive. The construction in the yards and sidings is simplified by paralleling the trolleys from the side-tracks for a short distance along the main line. This avoids the use of switch plates or similar devices. At some of these junction points the pantograph engages as many as six trolley wires at the same time.

The trolley wire is reinforced between the substations with two 500,000-circular-mil bare copper cables tapped to the trolley at intervals of 1,000 feet. A No. 0000 negative return wire is also installed between Rocker and East Anaconda. The wire is carried on the trolley poles and is connected to the cross bonds at intervals of 1,000 feet. The substations are normally connected together by these feeders, allowing an interchange of current. In emergency, either station can supply current to the entire system.

The locomotive equipment consists of seventeen 80-ton units, 15 for freight and 2 for passenger service. The freight locomotives are geared for slow speed and are operated in pairs for the main line service. The maximum free-running speed is 35 miles per hour. The two passenger locomotives are of the same construction as the freight units, but are geared for a maximum free-running speed of 55 miles per hour. A speed of 45 miles per hour is made with three passenger coaches on a straight, level track. These locomotives are of the articulated double-truck type with all the weight on the drivers. The cab contains an engineer's compartment at each end and a central compartment for the control apparatus. The central channels forming a part of the underframe are inclosed and are utilized as a distributing air duct for the forced ventilation of the motors. The air is conducted through the center pins, which are hollow, into the truck transoms and thence to the motors. The motors are of the commutating-pole type, wound for 1,200 volts and insulated for 2,400 volts, and provided with forced ventilation. The gear reduction on the freight locomotive is 4.84, and on the passenger locomotive 3.2. The double-unit, 160-ton locomotive is capable of giving a continuous sustained output of 2,100 horsepower. The motors are connected to the driving wheels by twin gears similar to those used on the Detroit River Tunnel, the Baltimore & Ohio, and the Great Northern locomotives.

The control equipment is multiple-unit, operating the four motors in series and in series-parallel. The two 1,200-volt motors are permanently connected in series. The controller provides ten steps in series and nine in series-parallel. The transition between series and series-parallel is effected without opening the motor circuit, and there is no appreciable reduction in tractive effort during the change. The transfer of circuits at this point is made by a special change-over switch, which is operated electropneumatically. The 2,400-volt contactors are operated from the 600-volt control circuit, and are specially constructed to separate the 2,400-volt parts from the coils and interlocks which carry the 600-volt current. The necessary insulation is obtained by large clearances and by the use of porcelain and mica insulation. The armature is connected to the contact lever by a wooden rod. The contacts, magnetic blow-out, and arc chutes are also especially designed to rupture the 2,400-volt arc.

Current is collected by overhead roller pantographs operated by compressed air. A 2,400-volt insulated bus line runs along the center of the cab roof. These bus lines are connected together by couplers between the two freight units, so that the current may be obtained from either one or two collectors.

The principal data and dimensions applying to the locomotives are the following:

Length inside of knuckles, 37 feet 4 inches.
Length over cab, 31 feet.
Height over cab, 12 feet 10 inches.
Height with trolley down, 15 feet 6 inches.
Width over all, 10 feet.
Total wheel base, 26 feet.
Rigid wheel base, 8 feet 8 inches.
Track gauge, 4 feet 8½ inches.
Total weight, 160,000 pounds.
Weight per axle, 40,000 pounds.
Wheels, steel tired, 46 inches.
Journals, 6 inches by 13 inches.
Gears, forged rims, freight locomotives, 87 teeth.
Gears, forged rims, passenger locomotives, 80 teeth.
Pinions, forged, freight locomotives, 18 teeth.
Pinions, forged, passenger locomotives, 25 teeth.
Tractive effort at 30 per cent coefficient, 48,000 pounds.
Tractive effort at one-hour rating, 30,000 pounds.
Tractive effort at continuous rating, 25,000 pounds.

Classification of work done.—A very complete survey of work done, conditions, and apparatus was furnished in a paper read before the Canadian Society of Civil Engineers, in December, 1913, by Mr. A. H. Armstrong, the well-known American expert, in which he discussed the methods of electrification and their actual application.

The electrical engineer has perfected several types of locomotives and different methods of distributing electric power to them, thus giving rise to what are known as several different "systems of operation." The term "system" is generally applied to the combination of locomotive and trolley or third-rail distribution, as the matter of power generation and transmission is common to all. The three systems considered for main-line electrification are as follows: Single phase, alternating; split phase, alternating; and high voltage, direct current.

The single-phase commutating motor has been in operation upon interurban electric railways for some years, said Mr. Armstrong, and a study of the history of these installations reveals some of the fundamental reasons why this type of motive power has not been more generally adopted. It has been found that the initial expense and cost of upkeep of rolling stock equipped with single-phase commutating motors is fully double that of cars having the same seating capacity and equipped with direct-current motors. No new installations have been made for the past three years, and the several single-phase roads are being changed over to direct current as fast as financial conditions will permit. The single-phase installations are listed in the following table; and on those roads whose names are preceded by asterisks the single-phase motors have been replaced with the direct-current type:

SINGLE-PHASE RAILWAY INSTALLATIONS IN UNITED STATES AND CANADA.

NAME OF RAILWAY.	Year.
Indianapolis & Cincinnati Traction Co.	1904
*Atlanta Northern Railway	1905
*Illinois Traction system	1905
Long Island Railroad—Sea Cliff division	1905
San Francisco, Vallejo & Napa Valley, California	1905
*Warren & Jamestown Street Railway	1905
Westmoreland County Traction, Derby to Latrobe, Pa.	1905
Spokane & Inland Empire Railroad	1906
*Toledo & Chicago Railway	1906
*Anderson Traction Co., South Carolina	1907
Erie Railroad	1907
Fort Wayne & Springfield Railway	1907
*Milwaukee Electric Railway (interurban division)	1907
New York, New Haven & Hartford Railroad	1907
*Pittsburgh & Butler Street Railway	1907
Richmond & Chesapeake Bay Railway	1907
Windsor, Essex & Lake Shore Electric Railway	1907
*Baltimore & Annapolis Short Line	1908
Chicago, Lake Shore & South Bend Railway	1908
Colorado & Southern: Denver & Interurban Railroad	1908
Grand Trunk Railway: Sarnia-Port Huron Tunnel	1908
Hanover & York Railway, Pennsylvania	1908
Shawinigan Railway, Quebec	1908
Visalia Electric Railway, California	1908
*Washington, Baltimore & Annapolis Electric Railway	1908
Rock Island Southern: Rock Island to Monmouth	1910
New York, Westchester & Boston Railway	1911
Boston & Maine: Hoosac Tunnel	1911

The introduction of the single-phase system was a result of the success of suburban and interurban electric railway operation and the extension of these lines over large areas, thus bringing into prominence the question of economical power distribution. It was recognized that a voltage higher than the commonly accepted standard of 600 volts was desirable upon the trolley in order to minimize the cost of installing feeder copper and substations. While the single-phase motor was being developed and installed upon interurban railways, careful attention was also being given to the question of the possibility of using direct-current motor equipments at higher voltages, and this resulted in the first 1,200-volt railway installation, on the Indianapolis & Louisville Traction Railway, operated in 1907. The success attending this operation led to other similar installations at both 1,200 volts and 1,500 volts, until it is now generally recognized, Mr. Armstrong asserted, that the high-voltage, direct-current system is without a competitor for all classes of suburban electric railways. It was a safe prediction to make, he stated, that no more single-phase motor equipments will be placed in operation in this country on new roads unless these roads virtually form extensions of existing systems.

The following table gives a list of the several high-voltage, direct-current installations in the United States and Canada:

HIGH-VOLTAGE, DIRECT-CURRENT RAILWAY INSTALLATIONS IN UNITED STATES AND CANADA.

NAME OF RAILWAY.	Voltage.	Number of equipments.	DATE. Month.	DATE. Year.
Indianapolis & Louisville Traction Railway Co., Scottsburg, Ind.	1,200	13	October	1907
Central California Traction Co., Stockton, Cal.	1,200	22	June	1908
Pittsburgh, Harmony, Butler & New Castle Railway, Eidenau, Pa.	1,200	30	July	1908
Washington, Baltimore & Annapolis Electric Railway, Baltimore, Md.	1,200	47	February	1910
Milwaukee Electric Railway & Light Co., Milwaukee, Wis.	1,200	32	March	1910
Aroostook Valley Railway Co., Presque Isle, Me.	1,200	6	July	1910
Oakland, Antioch & Eastern Railway, San Francisco, Cal.	1,200	25		1910
Southern Cambria Railway Co., Johnstown, Pa.	1,200	10		1910
Shore Line Electric Railway Co., Saybrook, Conn.	1,200	22	September	1910
Southern Pacific Railway (Oakland, Alameda & Berkeley division), Cal.	1,200	82	April	1911
Fort Dodge, Des Moines & Southern Railway, Boone, Iowa.	1,200	29	September	1911
Southwestern Traction & Power Co., New Iberia, La.	1,200	3	May	1912
Oregon Electric Railway, Portland, Oreg.	1,200	72	July	1912
Davenport & Muscatine Railway Co., Davenport, Iowa.	1,200	7	August	1912
Kansas City, Clay County & St. Joseph Railway, Kansas City, Mo.	1,500	22	June	1913
Piedmont Traction Co., Charlotte, N. C.	1,500	43		1913
Nashville-Gallatin Interurban Railway, Nashville, Tenn.	1,200	6	April	1913
Butte, Anaconda & Pacific Railway, Butte, Mont.	2,400	17	June	1913
United Railways Co., Portland, Oreg.	1,200	8	June	1913
Southern Traction Co., Dallas, Tex.	1,200	30	October	1913
Pittsburgh & Butler Railway, Pittsburgh, Pa.	1,200	13		1913
Pacific Electric (San Bernardino division), Los Angeles, Cal.	1,200	54	Building	
Tidewater Southern Railroad, Stockton, Cal.	1,200	4		1913
Portland, Eugene & Eastern Railway, Portland, Oreg.	1,500	38	Building	
Southern Illinois Railway & Power Co., Harrisburg, Ill.	1,200	5	September	1913
Jefferson County Traction Co. (Eastern Texas Electric Co.), Beaumont, Tex.	1,200	7	Building	
St. Paul Southern Electric Railway, St. Paul, Minn.	1,200	5	Building	
Michigan United Traction Co., Jackson, Mich.	2,400 1,200	20 40	Building Building	
Canadian Northern Railway, Montreal, Canada.	2,400	14	Building	
Canadian Pacific Railway, Rossland, British Columbia.	2,400	4	Building	

All of the foregoing roads in service are operating with the highest degree of success and no change of type of equipment has been made or contemplated.

The elimination of the single-phase motor as being unsuitable for the equipment of light electric railways has an important bearing upon the selection of systems for main line electrification. The limitations of the single-phase motor that lead to its failure in the interurban railway field do not appear to be lessened when it is considered for locomotive equipment, with the result that it is in use on but three of the twelve roads that are truly representative of electrified steam roads operating large electric locomotives.

There are other electrified steam lines, but the service on them more nearly approaches that of high-class electric interurban railways. There are also interurban systems where electric locomotives of considerable capacity are operated, but the class of service on such systems does not approach the exacting demands of main line passenger and freight operation.

The following table gives a list of converted steam lines on which the service consists of hauling main line passenger and freight trains behind electric locomotives of large capacity. An asterisk preceding the name of a road indicates that the work is under construction.

MAIN LINE ELECTRIFICATION—UNITED STATES AND CANADA.

INSTALLATION.	Year.	Type of locomotive.	System.	Voltage.
St. Clair Tunnel	1908	Geared	Single-phase alternating	3,300
New York, New Haven & Hartford.	1907	Gearless	Single-phase alternating	11,000
Hoosac Tunnel	1911	Geared	Single-phase alternating	11,000
Cascade Tunnel	1909	Geared	Three-phase alternating	6,600
*Norfolk & Western	1914	Geared, side rod.	Split-phase alternating	16,500
Baltimore & Ohio Tunnel.	1895	Geared	Direct current	600
New York Central	1906	Gearless	Direct current	600
Detroit Tunnel	1910	Geared	Direct current	600
Pennsylvania Terminal.	1910	Gearless, side rod.	Direct current	600
Butte, Anaconda & Pacific.	1913	Geared	Direct current	2,400
*Canadian Northern	1914	Geared	Direct current	2,400
*Canadian Pacific	1914	Geared	Direct current	2,400

It is a noteworthy fact that the use of the single-phase motor has not extended beyond the two original roads installing this type of equipment, the Grand Trunk and the New York, New Haven & Hartford (including the Hoosac Tunnel installation), whereas direct-current motors have been universally adopted in all the more recent electrifications with the single exception of the split-phase installation on the Norfolk & Western Railway.

The so-called "split-phase" system is comparatively a newcomer in the electric traction field, and it has not yet been subjected to the test of actual operation. It offers many attractive features, however, for heavy electric railway service. From experimental tests made, it seems reasonably certain that the split-phase locomotive can meet the demands of commercial operation with satisfactory reliability.

Confronted with the problem of main line electrification and the demand for a distributing system which would provide for the economical distribution of large units of power over an extended area, the Butte, Anaconda & Pacific Railway appreciated the need of higher direct-current voltage, and as a result made its first installation of 2,400 volts direct current, under which operation began on May 28, 1913. This installation marks an epoch in electric railway progress, as its success constitutes substantial proof that direct-current motor equipments can be constructed at a reasonable cost and operated in an efficient and reliable manner with trolley potentials as high as 2,400 volts. It has been characteristic of the installations operating at 1,200 and 1,500 volts that the reliability of the direct-current motive power has been in no way impaired by reason of using a higher trolley voltage; in fact, the maintenance cost of 1,200-volt motor equipments shows no increase over that of 600-volt equipments. A brush life of over 150,000 miles gives evidence of good commutator performance with practically no wear, and the increased insulation provided has been ample to insure reliability and low cost of maintenance. The transition from 1,200 volts to 2,400 volts direct current has also resulted in completely successful operation at this potential.

ELECTRIC LOCOMOTIVES.

Norfolk & Western split-phase locomotives.—One of the newest and latest departures is the equipment, by the Norfolk & Western Railway, of a mountain division for single-phase, or "split-phase," locomotive operation. The locomotives handle freight trains of 3,250 tons' weight, exclusive of the locomotive, at a speed of 14 miles per hour on a 2 per cent grade, and they will be operated at speeds up to 28 miles per hour on lighter grades. Four locomotives will be used on the heaviest grades, two in front and two at the rear of each train. They are arranged for multiple-unit operation in pairs, but no electrical connection will exist between the two ends of the train. The motors for these locomotives present a novel departure from existing practice in design for traction purposes. They are constructed without commutators, and follow the principles of the standard polyphase induction motor, retaining all the advantages in ruggedness and absence of complication which are characteristic of the latter type. As they utilize power which is originally in single-phase form as received from the overhead conductors, the current is passed through a phase-splitting device before reaching the motors, so that the equipment as a whole may be properly described as of the single-phase-polyphase type.

In detail, the electrical equipment of each locomotive comprises four polyphase induction motors of a total continuous rating of about 1,300 horsepower at 14 miles per hour. Each motor has windings for producing either four or eight poles so that the speed may be changed accordingly, and is equipped with a wound secondary in order to provide for the insertion of resistance and for connection in cascade for low speed at starting and for switching service. There are thus two running speeds, 28 and 14 miles per hour, and a switching speed of 7 miles per hour.

The motors are geared in pairs through jack shafts, cranks, and side rods to the driving wheels, the gear ratio being 85:18, and the driving wheels 62 inches in diameter. Each pair of motors is mounted on a truck with two driving axles and a pony axle, the latter carrying 30-inch wheels. The two trucks are coupled together by a Mallet hinge.

The trolley voltage is 11,000, and the frequency 25 cycles per second. Part of the trolley wire is fed direct from the 11,000-volt generator in the power house at Bluefield and part through transformers lowering the pressure from 33,000 volts, at which the outlying parts of the line are supplied. On each locomotive is a single transformer stepping the voltage down from 11,000 to approximately 750, provision being made for a slight adjustment of the secondary voltage. From this, secondary current passes through a rotating induction apparatus for transforming the phase relation, provision being made for suitable adjustment for keeping the phase voltages balanced.

The polyphase current then passes into the motors. These, as previously stated, have wound secondaries and slip rings arranged for cascade connection.

This type of induction motor, while quite unusual in the traction field, has been very successful in different forms in rolling-mill work and the like. It has several important advantages in this case. In the first place, the grades to be encountered are unusually heavy, and regenerative control will be a considerable advantage. This is true not so much on account of the saving in power as from the consideration of safety in descending grades. Incidentally, there will undoubtedly be a considerable saving in wear of brakeshoes and tires. In descending grades, the two units composing the head locomotive will be connected to pump their electrical energy back into the line and they will be loaded to their full capacity. When other trains are in the electric division, the saving will be considerable, as this method will lighten the load on the station and improve its load factor. When the descending train is the only one on the line, the power thus developed will be absorbed by rheostats in the power plant.

The locomotives are the first to be commercially used in this country with a combined jackshaft and gear drive. Four driving axles and two carrying axles are used, the wheel base being divided into two separate units or trucks, connected at adjacent ends by a hinge coupling. The carrying axles are mounted radially, and each main truck has two driving axles and one radial axle. The outer ends of the trucks are fitted with standard buffers and friction draft gear with standard couplers, the drawbar pull being transmitted through the truck frames to the train. The weight does not exceed 57,000 pounds per pair of drivers and is sufficient to produce a tractive adhesion for a maximum effort of 62,500 pounds per locomotive, the weight on each radial axle being not less than 20,000 pounds at the rails. The locomotive will, with forced ventilation, have sufficient capacity to exert continuously a tractive effort of 33,600 pounds.

A single cab supported on the trucks at suitable bearing points contains the operating and control apparatus of the locomotive. The cab is of the box form, provided with end doors and platforms for convenient passage between two or more locomotives when coupled together, and between the locomotive and train; in addition, side doors are provided at diagonally opposite corners. There are also side and end windows for lighting the cab. The apparatus is arranged along the center of the cab, making it conveniently accessible and leaving a clear, unobstructed passageway at either side.

The control apparatus, both air and electric, is located at one end of the cab, in such a manner as to leave an unobstructed view along the track. The operator's seat is placed so that there is a clear view of the signals.

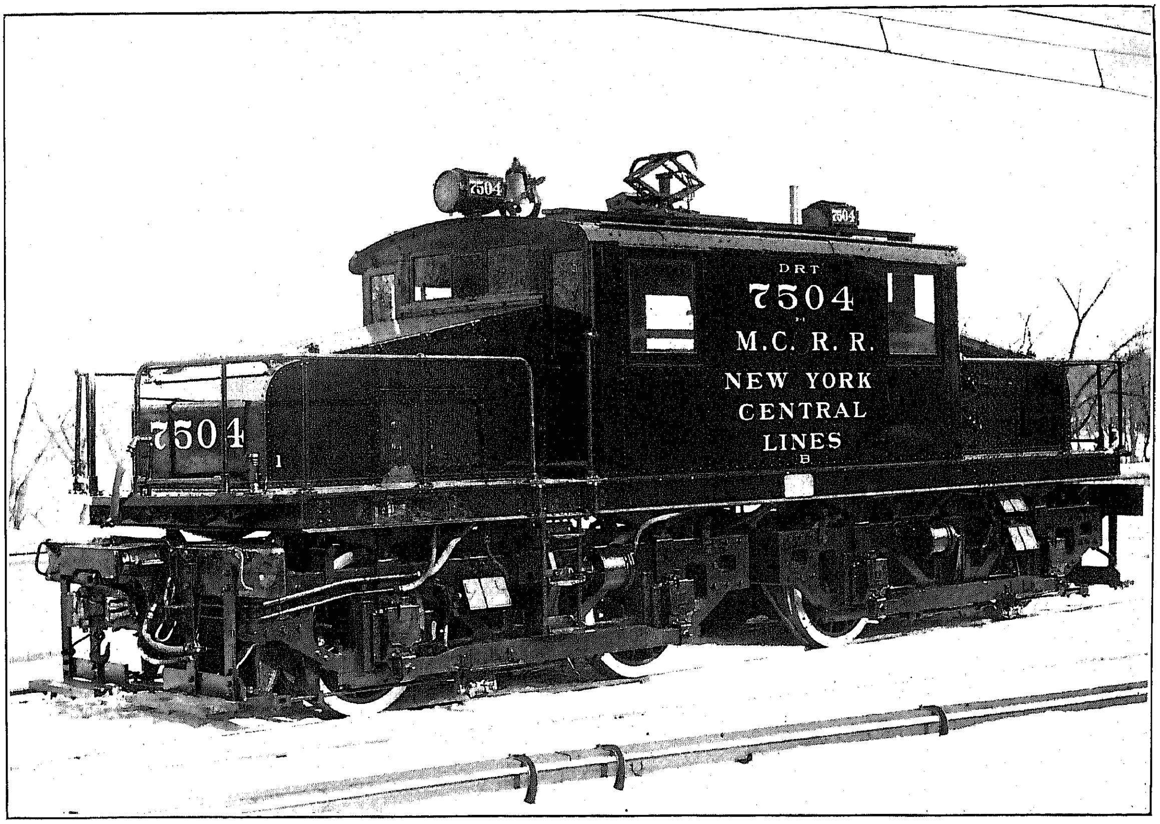
The motors are connected through twin gearing to a jackshaft. They are of the polyphase, 25-cycle, induction type with wound secondaries, which are connected in cascade for producing low speed in starting and switching. There are, as noted, two running speeds, 28 and 14 miles per hour, and a switching speed of 7 miles per hour. In starting with the 7-mile combination, the motors on each truck are connected in cascade, and the two sets of cascades are connected in parallel. Resistance is inserted in the secondaries at starting. In this combination the primaries are arranged for eight poles. With the 14-mile combination all motors are in parallel, connected for eight poles; and with the 28-mile combination the four-pole arrangement is employed, resistance being used on intermediate steps.

A multiple-unit system of control is provided for the independent operation of each locomotive, or for the operation of two units simultaneously from the control end of either, in whatever order or arrangement they may be coupled together. The control equipment is arranged and constructed to provide for the use of single-phase current from the pantograph trolley, which is connected to the primary winding of the main transformer through a suitable line switch, while from the secondary of the transformer, circuits are established through and in connection with the phase converter in such a manner as to deliver polyphase current to the main motors.

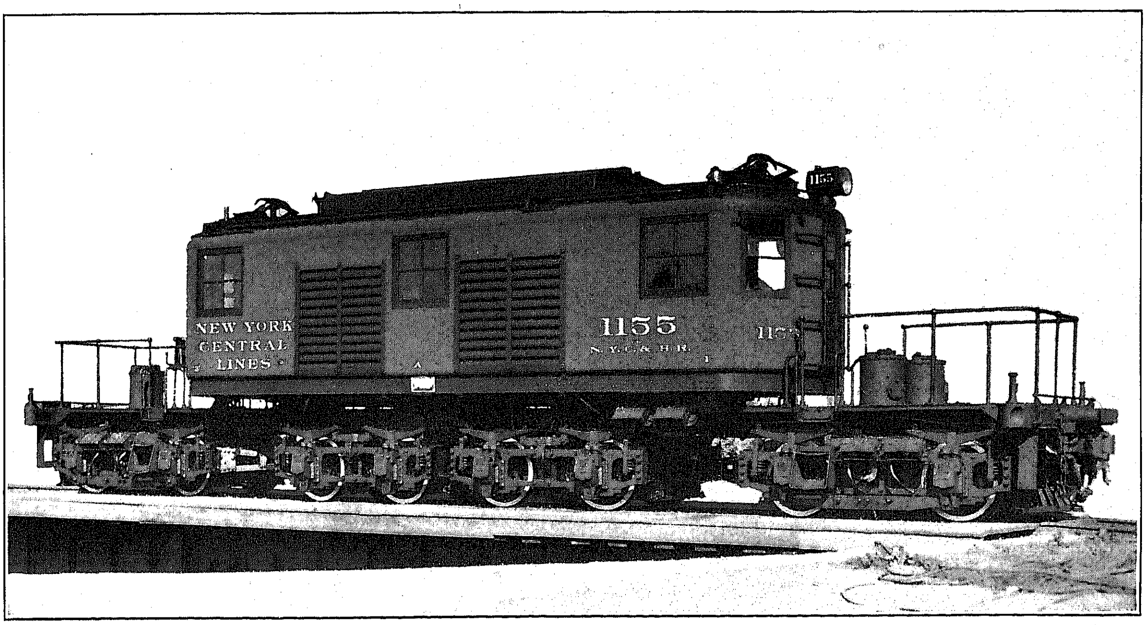
Each locomotive is provided with an air compressor driven from the phase converter through a multiple-disk friction clutch. This clutch is controlled by the main reservoir pressure, so that the compressor is operated only as required. Straight-air and automatic air brakes are installed, together with the necessary ventilating apparatus for the motors.

The use of the induction motor in place of the commutator motor for this installation involves an important consideration, in addition to those mentioned, namely, that of cost. On account of the space limitations combined with the particular speed specified, the induction motor worked out cheaper than the commutator motor. The space limitations dictated a long motor, small in diameter, and although a commutator motor would have been entirely practicable it would have been more expensive than the induction motor at the low speed required. At a somewhat higher speed the condition might have been reversed. Hence a decision between the two types must be based, not upon their operating characteristics alone, but upon these combined with cost under space limitations.

The contract calls for the manufacture and delivery of 26 130-ton electric locomotives of the single-phase-polyphase type, together with all required power-house generating machinery and transmission apparatus. The use of the two running speeds of 14 miles per hour and 28 miles per hour, which will be to a large degree maintained very closely, will under the

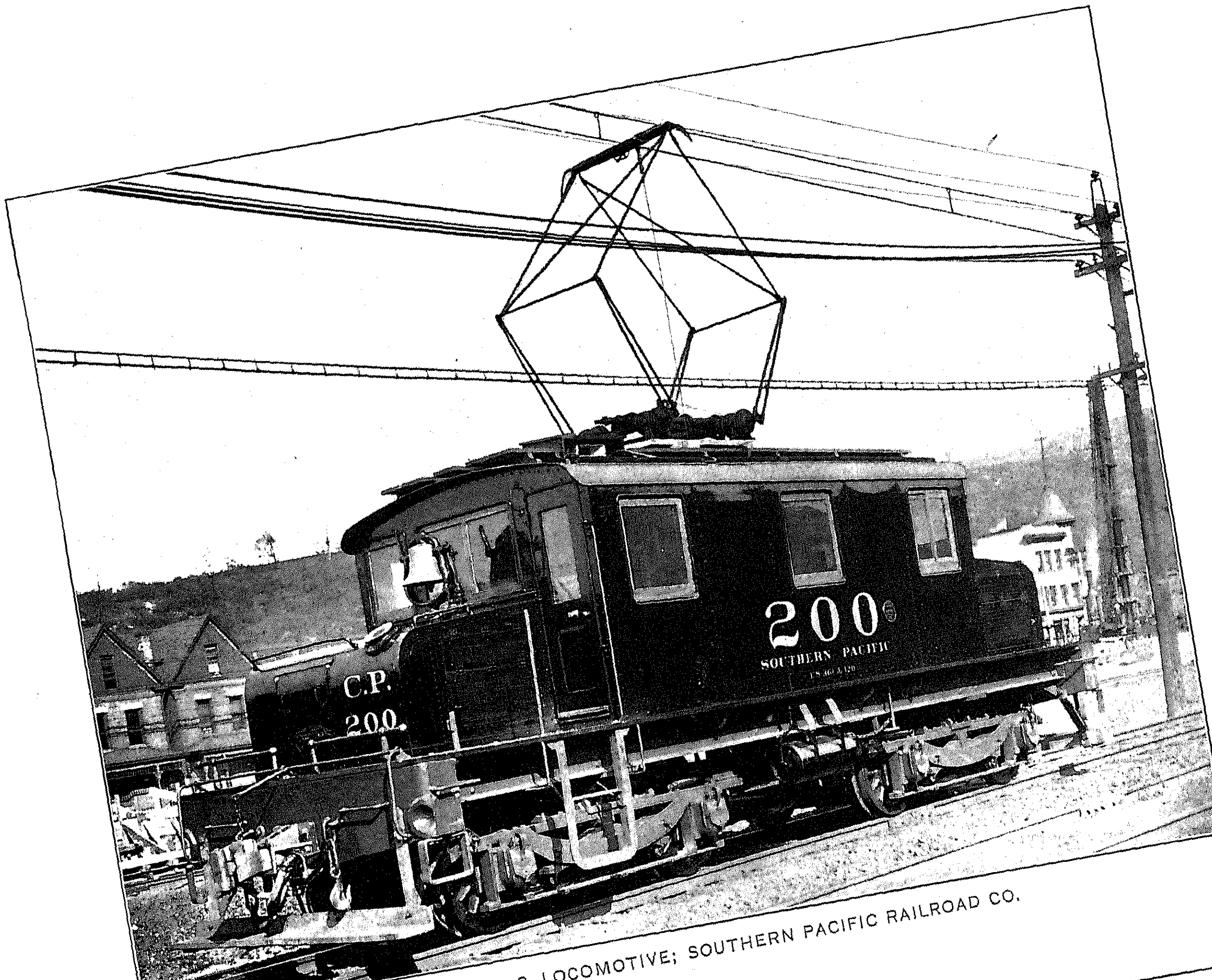


ELECTRIC LOCOMOTIVE.



600-VOLT LOCOMOTIVE.

(Face p. 408.)



800–1200-VOLT D. C. LOCOMOTIVE; SOUTHERN PACIFIC RAILROAD CO.

2,400-VOLT LOCOMOTIVE; BUTTE, ANACONDA & PACIFIC RAILWAY CO.

circumstances existing in this case be particularly applicable for the service, as the locomotives are intended for handling only "tonnage trains." These are loaded with coal originating in the vicinity, as the Bluefield-Vivian division serves the celebrated Pocahontas coal region, one of the largest coal fields in the world. The shipments of coal handled amount to 65,000 tons per day, and the trains weigh as much as 3,250 tons; and it is to facilitate the handling of this heavy traffic that electrical operation has been adopted.

As mentioned before, there are a number of grades on this section, the maximum being 2 per cent, and three Mallet locomotives, the most powerful type of steam locomotives built, have been required for each train, one locomotive being used at the head of the train and two for pushing. With the electric system and the present steam speed will be doubled. The extent to which this quick train movement will enlarge the capacity of the railroad is quite apparent. In addition, one of the present impediments to rapid operation of this section of the road is the existence of a 3,100-foot tunnel which is difficult to ventilate. This tunnel under electric operation will, of course, owing to the absence of smoke and noxious gases, offer no impediment to frequent train movement.

Larger locomotives for New York Central.—The number of electric locomotives in use on the New York Central Railroad has steadily increased, 16 having been purchased in 1913. Those of the latest type are the largest, weighing 110 tons, with materially increased capacity for continuous service. The weight of trains hauled out of the Grand Central Terminal, New York City, is increasing steadily, and some of the more important trains now weigh over 1,000 tons. It has therefore been deemed desirable to have engines for the maximum service with very great continuous capacity, ample overload, and high momentary rating. The new locomotives are able to exert practically the same tractive effort continuously that the previous locomotives could exert for one hour. The 10-ton increase in weight in the new machines is accounted for mainly by the greater amount of material in the motors, which are of larger capacity. The speed and torque characteristics, however, have been kept practically the same, but capacity has been provided for hauling approximately 40 per cent greater tonnage in continuous service. The previous 100-ton locomotives have a capacity for developing 1,460 horsepower continuously and 2,000 horsepower for one hour, and can develop as high as 5,000 horsepower for short periods. This corresponds to a tractive effort of 9,000 pounds at 60 miles per hour continuously, or 13,500 pounds at 54 miles per hour at the one-hour rating. The newest engines develop 2,000 horsepower continuously, or 2,600 horsepower for one hour. The equivalent tractive effort is 14,000 pounds at 54 miles per hour continuously, or 20,000 pounds at 49 miles per hour at the one-hour rating. They are able to haul 1,100-ton trains in continuous service between the terminal and Harmon, on the Hudson River, and are capable of operating 1,200-ton trains on level tangent track continuously at 60 miles per hour in emergency service.

The new machines are of identically the same type as the ten 100-ton locomotives bought earlier in the year, having articulated frames with bogie guiding trucks at each end. The cab, containing the engineer's compartment and that for the operating mechanism, is swung between the two parts of the frame on center pins. Each section is carried on two-axle trucks having a driving motor mounted on each axle. All the axles are therefore driving axles, and the eight motors are of the standard bipolar gearless type.

The motors are provided with forced-air ventilation and are electrically connected permanently in parallel in pairs, the pairs being connected in three combinations, namely, series, series-parallel, and parallel. They are insulated for 1,200 volts, so that if at any future time it should be desired to operate the locomotive on this higher voltage the pairs of motors could be changed from parallel to series connections and the same speeds and control combinations obtained as on 600 volts. Compared with previous types these machines have exceptionally large capacity and high efficiency, but the total weight, weight per driving axle, and "dead weight" are exceedingly low.

New Haven switching locomotives.—Approximately 8,000,000 people are served directly by the New York, New Haven & Hartford Railroad. Of all freight hauled in and out of New England by rail, this road handles 75 per cent. The bulk of this freight handled at New York is carried via the Harlem River division and the Harlem River and Westchester freight and transfer yards. Although the electrification of the New Haven road between New York and New Haven is not yet complete, the switching of all freight cars between Stamford and the Harlem River has been done successfully by electricity since 1912. The economies obtained by the use of the electric switch locomotives have exceeded all the expectations of those who are responsible for their adoption, and their operation is a source of satisfaction to the operating department and trainmen who have this work in charge.[1]

The three main switching yards on the New Haven System are the Harlem River yard, with a length of 23.3 miles; the Oak Point yard, with a length of 37.16 miles; and the Westchester yard, with a length of 22.29 miles; also the Van Nest yards, which are used for storage only.

In March, 1911, the first switching engine was placed in operation at Stamford, Conn. In August, 1912, the first switcher started to work in the Westchester yards; in September, 1912, the first in the Oak Point yards began work in float-dock service; and in August, 1913, the first began its operation in the Harlem River yards proper.

[1] Electric Traction, March, 1914.

The service performed by these locomotives in the Oak Point yard is of special interest. This is the terminal where all the cars on floats destined to the New England states are unloaded.

On account of the care required to keep a float from capsizing, it requires six movements to unload it and dispatch a train to the yard; also, six movements are necessary to load a float. The minimum time required to load and unload (12 movements) is 35 minutes. Six single-phase electric locomotives do the work of approximately twice the number of steam locomotives formerly used. A total of eight of these electric locomotives are sufficient for practically all of the switching work between Stamford and Harlem River Station. These are kept in service 24 hours a day, each making an average of approximately 140 miles in 24 hours with three 8-hour crew shifts. The six electric locomotives handling the work between Westchester yard and Harlem River during one month made 38,000 locomotive miles, consumed approximately 896,000 kilowatt hours of electrical energy at the locomotive, and handled approximately 65,000 cars which had a total weight estimated at approximately 1,000,000 tons. Practically all of these cars were transferred from floats. All of the heavy freight tonnage mentioned above is handled within the corporate limits of New York City, and the elimination of smoke by the use of the electric locomotive is another advantage which has a special interest to all residents in the vicinity.

There are 16 switching locomotives included in this installation. Each locomotive is equipped with four 125-horsepower, 25-cycle, single-phase motors with unit switch control. They weigh 80 tons and are able to exert a maximum tractive effort of 40,000 pounds with a clean, dry rail. The locomotives can exert a maximum tractive effort of 36,000 pounds for about three minutes at speeds up to 6 miles per hour, and a continuous tractive effort of 14,800 pounds at a speed of 11½ miles per hour. In practice it has been found that an electric switching locomotive can do the work of two steam locomotives because it can be operated both day and night. In fact, the first switching locomotive furnished has been in use for about 20 hours a day in the yards at Stamford. It is not expected that the maximum voltage on the motors will be reached in ordinary switching service, but it is available when climbing grades or on longer runs in the yards. The average operating potential is estimated to be 190 volts. The hour rating corresponding to this voltage, with current of 900 amperes, is approximately 125 horsepower per motor.

Arrangements have been made for a large bridge, known as the interconnecting railroad bridge, between Harlem River and Long Island City, which will physically connect the Pennsylvania and New Haven systems. Electricity as a motive power will be used entirely for handling all traffic over this bridge.

Piedmont & Northern 1,500-volt locomotives.—The Piedmont & Northern lines, Charlotte, N. C., are placing in commission six new 1,500-volt, direct-current, electric locomotives on the Greenville, Spartanburg & Anderson division of the system. These locomotives weigh 63½ tons, with all the weight on the drivers, have the box type of cab extending nearly the entire length of the underframe, and are designed for heavy freight service. At the normal rating of the four motors, with which each locomotive is equipped, operated on 1,500 volts, two in series, they can develop a tractive effort of 17,500 pounds and a speed of 21 miles per hour. The locomotives handle trains of 800 to 1,000 tons, gross weight.

The Piedmont & Northern lines comprise two main divisions, which, when entirely completed, will embrace 280 miles of track. All these lines operate on 1,500 volts direct current. Energy is purchased from the Southern Power Co., and is delivered from the transmission lines to two substations for the Piedmont Traction Co. On the southern division of the road there are four substations. The lines have a very heavy freight traffic and transport great quantities of cotton from shipping points to mills along the route, and, in turn, fabric from the mills to connecting stations for distribution to distant markets.

In these locomotives the cab is open as far as is consistent with the location of the apparatus therein. While this apparatus is grouped in the central section, it is not located in a compartment separate from the engineman's operating cabs. Convenient passageways run along the sides and connect with the operating position in each end. The underframe consists of four 10-inch steel channels extending the entire length of the platform. These channels are tied together by heavy end-frame box-girder castings and bolster plates, each channel being riveted to the webs of the end-frame castings and to the top and bottom bolster plates. The bolsters are built up of 18-inch by 1-inch plates, the top bolsters being carried clear across the platform and riveted to all four longitudinal sills. The two center channels are inclosed throughout with steel plates riveted to the sills and carrying the center castings, which are bolted to them. The space between the center sills serves as a reservoir for distributing air from the blowers to the motors. Openings in the floor of this reservoir admit air from it through suitable intake pipes to the backs of the motors.

The two four-wheel trucks of the swivel type are designed for heavy freight work, and conform to M. C. B. standards. The wheels are solid rolled steel, 36-inch diameter, and the axles have 5½-inch by 10-inch journals. The air brakes are the combined straight and automatic type.

The locomotive is driven by four 600/1,200-volt box-frame commutating-pole motors, insulated for operation at 1,500 volts. Each motor is geared to an axle. The gear ratio is 65 : 18, making the gear reduction 3.61. The continuous capacity of each motor is 200 amperes under forced ventilation, and the one-hour capacity is 269 amperes. For the complete equipment of four motors on a locomotive this is equivalent to a continuously sustained tractive effort of 11,200 pounds at the rail. The motor is inclosed and is designed especially for locomotive service. Through the method of forced ventilation employed, air is circulated over the armature and field coils, over and through the commutator, through longitudinal holes in the armature core, and thence exhausted through openings in the bearing head.

The multiple-unit control is arranged to operate the four motors in series and series-parallel connections. The transition between series and series-parallel is effected without opening the motor circuit, and there is no appreciable reduction in tractive effort during the change. This smooth transition between control points permits operating the motors close to the slipping point of the wheels throughout the entire range of acceleration without sudden fluctuations of tractive effort.

One of the distinctive features is the convenient manner in which the apparatus is arranged in the central section of the cab so as to afford ready access to all parts for inspection, cleaning, adjustment, or repair. The main motor rheostat boxes are mounted in banks in an inclosed sheet-steel compartment in the cab center. This compartment extends from the floor to the roof and is accessible through doors opening into the passageways on the sides. The floor in the compartment is open, and it is surmounted by an open monitor deck. Thus there is a continuous draft of air rushing up through the compartment while the locomotive is running, affording exceptionally good ventilation.

The blower set for ventilating the motors has a capacity of 2,000 cubic feet per minute, and is driven by a series-wound motor of the railway type. Air is taken from the exterior through a suction box with side louvers underneath the platform at the center. Current at 600 volts for the operation of the blower, the air compressors, the contactors, and the light is furnished from a tap taken from the dynamotor.

Current is collected by an overhead pantograph trolley pneumatically controlled. On some of the ocal lines which form the system the overhead construction is not adapted for the pantograph trolley, and in order to operate over such lines the locomotives are equipped also with pole-type trolleys and trolley wheels. Some of these local lines are operated on 600 volts, and in some cases as low as 500 volts, direct current. A change-over switch is installed for cutting out the dynamotor while the locomotive is operating on low-voltage circuits, so that in such cases the current for the auxiliary control and supply circuits is obtained direct from the trolley circuit. This change-over switch is protected by an automatic relay, which makes it impossible to connect the 1,500-volt trolley current to the auxiliary circuits of the locomotive.

Results in electric locomotive operation.—With regard to results obtained under electrification, Mr. E. B. Katte, chief engineer for electric traction, New York Central Railroad, stated at the meeting of the New York Railroad Club, March 20, 1913, that at that time the Hudson division was operating 56 trains a day, equivalent to 7,000 multiple-unit car-miles, and the Harlem division was operating 72 trains a day, equivalent to 7,800 multiple-unit car-miles. The average number of trains which operated in and out of the Grand Central Terminal was 525 a day. A new record for reliability had been made as compared with preceding years, namely, the electric locomotives had operated 4,709 miles and the multiple-unit suburban cars 10,798 miles for each minute of detention due to electrical causes. Likewise, the multiple-unit cars had operated 12,374 miles per minute of detention due to mechanical causes. The average number of miles of operation per minute of detention on the whole electrical division due to all electrical and mechanical causes, including line trouble, etc., was 4,861 in 1912, 1,200 in 1911, and 1,785 in 1910. A table, which classified all detention troubles and mileages for every month of 1912, showed that the company operated 1,351,577 locomotive-miles and 4,297,633 multiple-unit-miles. The electric locomotives and multiple-unit cars had been in operation for more than six years. During 1912 the maintenance and renewal cost of the locomotives, including shop expenses, painting, etc., was 3.34 cents per mile, compared with 3.2 cents in 1910 and 3.08 cents in 1911, making the general average, say, 3.33 cents. Similarly, the maintenance and renewal cost of the multiple-unit cars was 1.8 cents per car-mile in 1912, 2.1 cents in 1911, and 1.9 cents in 1910, but Mr. Katte estimated that the average cost would run about 2 cents per car-mile.

GENERAL FEATURES OF RAILWAY MOTOR IMPROVEMENT.

It is, of course, extremely difficult to enumerate and sum up all the improvements which, step by step, have brought the electric railway motor up to its present condition of efficiency and durability, but an excellent summary has been made by Mr. W. N. Storer. The evolution of the modern railway motor began in the early eighties and is practically all confined to a period of 30 years, which may be divided into about five stages, as follows: First, the period embracing the experiments of the early inventors, such as Field, Henry, Daft, Edison, Van Depoele, Farmer, Bentley, Knight, Short, and Sprague; second, the period covering the exploitation of the double-reduction motor between the years 1886 and 1891; third, the period from 1891 to 1907, covering the development of the single-reduction motor of the straight-series type; fourth, the period from 1907 to 1911, covering the development of the commutating-pole motor; fifth, the period beginning in 1911, not yet completed, covering the era of economy in operation.

The motors at the end of the third stage may be said to have had embodied in them practically all of the improvements which had been developed prior to that time, and the following features are now common to all railway motors: Inclosed type with cast-steel frames; four laminated radial pole pieces bolted into the frame; mummified strap-wound field coils insulated with asbestos paper between adjacent turns, the entire coil impregnated in a vacuum; large armature shafts carried in bearing housings extending inside of the armature at the pinion end and inside the commutator at the front end; bearings well lubricated by the use of oil-soaked waste; separate oil wells for gauging the depth of oil and for receiving fresh oil; efficient oil throwers as a preventive of the oil reaching the interior of the motor; spring packing of field coils to counteract the effect of shrinking insulation, and thus prevent loosening; improved methods of holding motor leads to prevent vibration and breaking; two-point suspension of gear cases; commutator cover with simple and reliable cam-locking device; slotted drum-wound armature; ventilated armature; form-wound armature coils assembled in sets of three coils each; armature core and commutator assembled on the spider; armature bands laid in grooves in the armature coil; coils protected by asbestos hoods on the commutator end; high-grade insulation commutators with mica extending beyond the copper, both on the inside of the commutator and at the end next to the windings, to prevent short circuits; improved brush holders with high-grade insulating tubes protected by brass shells where clamped and by porcelain sleeves to give creepage surface; brush holders with adjustable tension and frictionless springs; high-grade carbon brushes; and many other small details which contribute to the success of the motor but can scarcely be enumerated.

The inclosed type of motor resulted from the large amount of trouble experienced from mud and water splashing into the early types and causing their insulation to break down. The use of the four radial poles followed the attempt to get the most compact as well as the lightest design for street-car motors.

Laminated pole pieces were introduced to decrease the loss from eddy currents in the pole faces, which, with the high inductions introduced with the slotted armature and small air gaps, increased greatly the total loss in the motor. Later the generator practice of saturating the pole tips by cutting off alternate pole tips from the punchings was introduced.

The use of mummified strap-wound field coils with asbestos insulation has become practically universal, and the use of round wire is permitted only on the smallest sizes of motors, where no gain is secured by the use of the flat copper ribbon. This type of field coil has been a wonderful improvement over the earlier types. With heat-proof insulation in the interior of the coil, it is able to withstand a much higher temperature, and the external insulation, which is completely filled with varnish, etc., makes it practically waterproof as well. Some motors had field coils of copper ribbon insulated with asbestos between turns. They were, however, wound in metal bobbin shells or spools and could not be wound tight enough to prevent the chafing of insulation and grounding. The mummified construction eliminated this trouble and has made a solid coil which, when used with the spring packing, is held perfectly tight. The use of springs back of the field coils to insure their being held firmly at all times has been a great improvement in the motors. It prevents the breaking of leads and chafing of insulation, which would result in grounded field coils.

Probably no improvement has been more marked or has done more to keep the motor cars out of the repair shop than the introduction of the standard type of bearing housing and method of lubrication. With the old grease lubrication it was no uncommon thing for armature bearing shells to be replaced after 3,000 miles of service. The life of the bearing on the motor may now be almost anything up to 300,000 or 400,000 miles. This extraordinary result is due to the excellent design of the bearing, which has the waste packed against the shaft on the low-pressure side, with the pressure of a column of waste over it, the oil being fed from below, coming from the well, which may be gauged at any time to see that the oil is kept at the proper level. This type of bearing has been universally adopted. It is scarcely necessary to add oil to the bearings more than once a month, so that not only is the cost of lubrication reduced to a negligible quantity, but the cost of maintaining the bearings and the loss due to the armature getting down on the pole pieces, which was a fruitful source of expense with the old bearings, have been practically eliminated.

The modern armature is a very different piece of apparatus from that of 20 or 25 years ago. Then either the armatures were hand wound or the coils were wound on a form and driven down on the ends of the armature with a mallet in the process of winding them. The evolution from that type to the one used at present has been gradual. Some early motors had only one armature coil per slot; others had two coils per slot or three coils per slot. A later motor introduced the barrel-shaped armature winding with the ends left open to provide circulation of air through the coils, and another had form-wound coils with sloping ends bound firmly on them. The modern type has the coils projecting straight out, banded to the coil support, and completely covered with canvas or asbestos cloth caps. The asbestos hoods on the front ends of the armature windings were introduced to prevent the damage incident to flashing, which may occur from any cause and is liable to set fire to a canvas covering.

The modern brush holders are a great improvement over the earlier form not only in accuracy of adjustment but in simplicity of insulation, substantialness of design, and the use of adjustable frictionless springs. Sluggish brush holders and inaccurate adjustments used to be fruitful sources of bad commutation and flashing, but have been almost entirely eliminated.

Another improvement introduced was the use of longitudinal holes through the armature core, that served the double purpose of providing paths for circulation of air and of "saturating" the iron beneath the armature slots, with thereby improved commutation. The saturation has been largely abandoned on later motors, but the air ducts are continued.

Another improvement for small motors is the armature spider, which carries not only the armature core but the commutator and thus permits the easiest possible renewal of bent or broken armature shafts. It also stiffens up the shaft in the spider, gives a much larger diameter for carrying the armature punchings, and holds them tighter. There is less possibility of relative motion between the armature core and the commutator, as both are keyed to comparatively large diameters on the same spider.

Coming at a time when the straight-series motor had thus reached a high state of perfection, the commutating-pole motor introduced in 1907–8 was an immediate and unqualified success. It had the benefit of all of the experience gained in the design and operation of the earlier motors and, added to that, the use of the commutating pole, which eliminated the last serious objection to the direct-current street-car motor, namely, the troubles incident to the commutation of the current. However, the commutating pole was not the only new feature. Intensive study of the subject led to still further minor improvements in the motors, and some very valuable features were introduced. Among them was the two-turn strap-wound coil, which was a triumph in the art of armature winding. The method of forming the coils used in this motor obviates all of the difficulties which had previously been experienced with that type of coil. It gives increased efficiency, larger capacity, better insulation, and more substantial construction than the ordinary wire winding.

The high-grade carbon brushes which came into extensive use about the same time, the undercutting of the mica on the commutator surface, and the sparkless commutation due to the commutating pole have practically eliminated wear on the commutator and greatly increased the life of the brushes. The amount of carbon and copper dust originating in the motor, which would tend to reduce the efficiency of the insulating surfaces, is therefore very small. This feature is of the utmost importance in the motor to be used on high-voltage circuits and greatly increases its reliability. Without it the high-voltage motor would have been a difficult, if not a commercially impossible, problem. With it the modern motor operates better on 1,500-volt circuits than the old motor did on 600 volts.

Mr. Storer discusses other elements of improvement, notably those involved in the attempt to reduce the weight, and holds that in general it is dangerous to make radical reductions in the weight of railway motors. The motors built 10 years ago were lighter in weight than the standard motors of to-day, but they were not nearly so reliable. For instance, a reduction in the size of armature shafts, which have been brought to their present generous proportions by years of hard experience, even though accompanied by the use of heat-treated material, is dangerous. Heat-treated materials have not yet reached the stage where they can be considered as standard, and until the methods of heat treating steel are much better understood by the general run of manufacturers and it is possible to obtain more uniform results by such treatment, it is better to make shafts strong enough to stand the service required of them without a resort to heat treatment.

The use of a coasting-time clock and of similar devices has drawn attention to the tremendous waste of power due to inefficient handling of equipment. It is said that the coasting-time clock, by putting a premium on rapid acceleration and on the maximum amount of coasting, has resulted in a saving of power consumption in some places of 20 per cent to 25 per cent, or even more. Efficient handling of the cars may in some cases result in so much less heating in the motors as to permit the use of a smaller size of motor, which will thus effect a reduction in weight without a decrease in mechanical strength.

Another method for reducing the weight of the equipment is the use of ventilated motors. For some years past the use of forced ventilation has been common on locomotive motors, and some motors for street-car service as well. The motors on the Long Isand Railroad have, for example, been operated for several years with forced ventilation secured by the use of small motor-driven blowers. The circulation of the external air through the internal parts of the motor is very effective in carrying off heat and increases very largely the continuous capacity of the motor. The same result may be brought about by the use of perforated covers on the motor or of a fan on the armature shaft arranged so as to draw air through all parts of the motor. Either method is very effective and is quite satisfactory where the dust and dirt do not offer a serious obstacle.

Undoubtedly the most positive power saver which has been introduced with the interpole motors in the last two years is field control. This, as is well known, is simply a revival of the old control system, used in some of the earliest railway motors. The early double-reduction motor made the most extensive use of this, since the control was entirely by commutating the field, and employed no external resistance at all. It was used to a greater or less degree in these motors and in one or two of the single-reduction motors as well. However, the commutation with slotted armatures was not good enough, and the points involved in the selection of equipments and the operation of motors were not well enough understood at that time to make the system a success. It was dropped nearly 20 years ago and was not revived to any great extent until it was applied on the locomotives of the New York, New Haven & Hartford Railroad in 1906 and 1907. These had single-phase motors of the series-compensated type, which permitted a wide range of variation in the field strength without impairment of the commutation. The system in this instance worked with marked success. Its later application to the commutating-pole motors on the giant Pennsylvania locomotives used for the New York terminal was also an entire success, so that the engineers of the company which had furnished both of these types of locomotives were satisfied that this system of control could be used safely with any size of motor. The trial equipment placed in service on the Metropolitan Street Railway in New York City nearly two years ago met with just as great success as that of the locomotives, and the decrease in the energy consumption of this car equipment as compared with the standard type of equipment in use was quite remarkable. A motor of very slow speed was used, and the resistance was normally cut out of circuit before the car reached a speed of 8 miles per hour. Higher speeds were obtained by weakening the fields of the motors. The maximum speed obtained was hardly as high as that of the standard equipment, so that a part of the saving of power resulted from the lower speed, but the larger part of it was undoubtedly due to the use of field control.

PASSENGER TRAFFIC AND FARES.

The subject of fares is obviously one of vital importance to every street and electric railway, as upon the income derived from transportation depend the welfare and prosperity of the line, the ability to give good service, the proper upkeep of the system in all its physical details, the payment of wages acceptable to the employees, the increase of facilities for the public, and the introduction of improvements. Even if some of these requirements and other financial necessities are met out of new capital, it is not possible to enlist that capital unless it can be shown that the existing investment enjoys a fair return; so that it all comes back to rates and fares. In practically all instances the fares now in existence are fixed by franchise, by agreement with the municipality, or by valuation of the property, but the elements and bases, in fact the very principles, referred to in determining rates and fares, remain a subject of constant discussion and experiment. Various aspects of the problem are presented in the reports made at Chicago in October, 1912, to the American Electric Railway Association by the committee on determining the proper basis of rates and fares, which reached at least one definite conclusion, as follows: "In a business such as that of electric railways where approximately 33⅓ per cent to 40 per cent of the traffic is handled within 3 to 5 hours out of the 24, this representing practically the lowest load factor of any public utility, and where the cost of living and consequent wages paid are increasing by leaps and bounds, it is essential that the present 5-cent fare be limited in distance, and for the street railways of $5,000,000 annual gross earnings and less it is apparent that the length of ride should not be over 4 miles."

A separate report by a member of the committee, Mr. Henry G. Bradlee, presented data as to the conditions under which roads could be operated with reasonable profit and return on the investment, assuming 3 per cent for all wear and tear, 1½ per cent for taxes, and an average of 8 per cent on the securities, making 12½ per cent net that must be earned to provide for obsolescence and depreciation, pay taxes, and attract capital to an industry in which the investment needed doubles on the average once in seven years, in order that towns and cities may be adequately served. The data available, however, would indicate that there are very few street railways in the country paying 8 per cent dividends and setting aside 3 per cent for depreciation, etc., as they do not earn it under present conditions. The table based on actual conditions as reported and analyzed by Mr. Bradlee is given herewith. From the reports made it appeared that only in the larger cities could 25 5-cent-fare passengers per half trip be counted upon. This would make the maximum receipts per half trip $1.25, which would be the limiting factor in determining the distance over which the car could be profitably operated. It would appear from the table that even in the larger cities a distance of from 3½ to 4 miles for a 5-cent fare is the maximum length of trip per passenger for profitable operation. As a matter of fact, there are a considerable number of large cities where the length of ride would average over this.

TABLE SHOWING INVESTMENT, OPERATING EXPENSES, ETC., FOR 20 SELECTED ELECTRIC RAILWAYS.

COMPANY.	Dollars investment per dollar of gross receipts.	Operating expenses per car-mile (cents).	Number of passengers per half round trip (5-cent fare).	Maximum length half trips for profitable operation (miles).
Annual gross receipts more than $1,000,000:				
A	$3.15	14.96	22.40	4.54
B	3.25	18.33	22.80	3.69
C	4.40	18.50	25.40	3.09
D	4.00	19.60	24.40	3.11
E	3.30	16.30	17.00	3.06
F	3.90	19.00	15.60	2.10
G	5.55	19.90	22.20	1.71
H	3.03	14.22	17.50	3.82
I	4.97	15.00	27.00	3.40
Annual gross receipts more than $750,000 and less than $1,000,000:				
A	3.00	18.40	13.20	2.24
Annual gross receipts more than $500,000 and less than $750,000:				
A	3.90	18.30	14.40	2.02
B	3.00	12.60	13.00	3.22
Annual gross receipts more than $250,000 and less than $500,000:				
A	3.80	18.60	15.30	2.16
B	4.40	12.00	13.40	2.51
C	4.20	13.70	8.70	1.51
D	4.40	13.70	7.40	1.21
Annual gross receipts less than $250,000:				
A	3.70	17.70	19.00	2.88
B	4.50	15.20	17.00	2.44
C	3.70	14.80	12.60	2.28
D	4.20	12.70	6.60	1.23

Mr. Bradlee stated that the figures derived would indicate quite clearly that urban street railway lines exceeding 4 miles in length must be a burden to the company rather than a source of profit, if operated for a 5-cent fare, and that an additional charge should be made on all lengths of haul exceeding 4 miles if the roads would earn a sufficient return to meet the higher expenses of operation and attract the new capital required for the extension of the industry.

Mr. Frank R. Ford, another member of this committee, filed a valuable memorandum as to existing rates and fares within the metropolitan areas of New York, Chicago, Boston, and Philadelphia. It summed up the general conditions existing at the end of 1912 in these four great cities. The metropolitan area of each of these cities has been assumed as that embraced within a circle of 16 miles radius, the center of which is located at the city hall, thus including 804 square miles, or 514,820 acres.

The United States census of 1910 showed a population for these metropolitan areas of approximately the following:

New York	6,198,440
Chicago	2,339,090
Philadelphia	1,940,833
Boston	1,572,079
Total of four cities	12,050,442

The magnitude of the electric railway interests of these four metropolitan cities is apparent when it is realized that they serve approximately one-third of the total population of urban localities of 8,000 inhabitants or more in the United States, represent a capitalization of approximately $1,250,000,000, and have gross revenues of over $200,000,000, equivalent to one-third of those of all the electric railways of the United States.

The urban and suburban passenger traffic of these cities is transported almost entirely by three systems: (*a*) Surface electric railways, (*b*) rapid transit systems of subway or elevated railroads, (*c*) steam railroads (in some cases electrified).

In New York City the rapid transit systems of elevated and subway lines carry a larger proportion of urban passengers than in any other American city, the number of such passengers carried by these systems in Greater New York in 1910 being 768,122,000, as compared with 763,140,000 on the electric surface lines, or about 50 per cent of the total. In Philadelphia, where the proportion of subway and elevated railroad mileage is the smallest for these four cities; approximately 8 per cent of the electric railway passengers in 1910 traveled on the subway and elevated line and 92 per cent on the surface railways.

The proportionate passenger traffic handled by the steam railroads is small as compared with that of the electric railways. In Philadelphia, for instance, where steam suburban railroads are noted as being among the best in American cities and where other rapid-transit facilities are limited, the total number of passengers carried in one day in 1910 was equal to less than 6 per cent of the number carried by the local electric railway system.

New York fare limits of electric surface lines.—In metropolitan New York the surface electric lines are divided geographically by the rivers into one principal system for Brooklyn, two for Manhattan and The Bronx, and one for New Jersey, with a few smaller independent companies on the outskirts. The rates of fare have been determined largely by the original franchises, which were based on early political boundaries. The 5-cent rate of fare for Manhattan Borough gives a maximum ride of 13.41 miles from the city hall to the northern limit. Similarly, the 5-cent rate from the Manhattan side of the East River bridges carries to practically any part of the built-up district of Brooklyn and Queens.

In the Borough of The Bronx, the next 5-cent zone, making a 10-cent limit from the city hall, extends beyond the 16-mile circle, and this is also the case for the central part of Long Island, although on its north and south shores the limits of the circle run from 15 cents to 20 cents from the city hall. In Staten Island (Richmond Borough) and in New Jersey, because of the disconnected locations of the various communities, the 16-mile circle practically coincides with the 20-cent limit if 5 cents for the Hudson River tunnel fare be included.

Thus the maximum ride to the edge of the metropolitan district varies from 0.6 cent per mile in Greater New York to 1¼ cents in New Jersey. In other words, to the north and east of the city hall, where the traffic is densest and the municipal boundaries are most extended, the rate per mile is approximately one-half the rate to the west and south.

Chicago fares.—In Chicago the traction settlement of 1907 imposed a 5-cent fare to the city limits on lines of the two large street railway systems. This limit is approximately 10 miles to the south, west, and north of the business center, giving a maximum ride at approximately one-half cent per mile. Beyond this limit the next 5-cent zone or 10-cent limit from the city hall carries a passenger from 3 to 5 miles farther. The 15-cent limit approximately coincides with the 16-mile circle, giving a maximum ride at about 1 cent per mile, this, however, representing an average of 2 cents per mile for the two outside zones as compared with one-half cent for the inner zone. The electric lines outside of the inner 5-cent fare limit in some cases are operated in connection with the city surface railways, and in others with the city elevated system.

Philadelphia fares.—In Philadelphia practically all of the street railways within the city limits are operated by one company at the 5-cent rate, and the same is true with respect to the adjacent portion of New Jersey. The 5-cent zone extends approximately 5 miles to the west of the city hall and 10 miles to the north, giving a maximum ride from the center at the rate of 1 cent per mile westwardly and one-half cent northwardly. Outside of the 5-cent limit, with few exceptions, the suburban trolley systems are independent. The second 5-cent zone, making a 10-cent fare limit from the city hall, extends from 8 to 11 miles from the center on the west, from 12 to 14 miles on the north, and in New Jersey (exclusive of ferry fare) from 6 to 8 miles out. The 15-cent fare limit on the west extends from 10 to 13 miles from the city hall, and on the north practically coincides with the 16-mile circle, while in New Jersey it extends from 8 to 14 miles from the center. The 20-cent limit on the west varies from 13 to 16 miles, and in New Jersey extends from 10 miles out to the 16-mile circle, although in places this circle overlaps the 25-cent limit both to the west and in New Jersey. Consequently, maximum fares within the 16-mile circle vary from 15 to 25 cents, or approximately from 1 to 1½ cents per mile.

Boston fares.—The electric transportation system of Boston has been developed along somewhat different lines from those followed in the other cities, in that the subway and elevated lines are operated jointly with and as an integral part of the surface system. The rapid-transit lines transport by wholesale passengers from the center of the city to transfer distribution points in the near-by suburbs. There free transfer is made to the surface lines in terminal stations without the use of tickets. It is consequently impracticable for statistical purposes to separate the rapid-transit and surface systems of Boston. The electric transportation business is principally conducted by two systems, one in the central portion of the metropolitan area, the other in the suburbs. There are also one other considerable suburban system and two interurban lines.

The 5-cent fare limit extends about 5 to 9 miles from the center of the city, giving an average rate of 0.7 cent per mile for these maximum distances. The 10-cent limit extends from about 8½ to nearly 14 miles from the center, producing an average rate of about 0.9 cent per mile for these total distances. The 15-cent limit extends from about 13 to 16 miles from the center, producing an average rate of about 1 cent per mile for the total distance.

The 10-cent limit of the electric roads practically marks the limit of the daily travel, which corresponds with the commutation travel of the steam roads. Beyond this 10-cent limit, nearly all of the regular traffic is handled by the steam railroads. This limitation of the area of electric travel is due to the lack of a real rapid-transit system extending any great distance from the center of the city, the time taken by the surface cars being too great to attract the regular traffic.

In all four cities the central business and residential districts constitute a zone of 5-cent cash fares. Transfers are practically universal, although in Philadelphia 3 cents is charged for exchange tickets (a form of transfer), and in Boston the same charge is made for transfer to the lines of an independent system. Upon some of the suburban lines around Boston a 6 cent fare is charged.

Fare limits of elevated and subway lines.—In these metropolitan cities, upon the street surfaces of the business districts becoming overcrowded, and with the extension of the residential areas, rapid-transit lines of elevated or subway railroads have been established, these usually being comprised within the limits of the central 5-cent fare zone of the surface railways.

In New York City the 5-cent fare limit of the elevated and subway system of Manhattan and The Bronx, under municipal ownership and private operation, has been extended to the north for a space of approximately 4 miles beyond the 5-cent limit of the surface system. This system has also been extended into Brooklyn so as to form a 5-cent fare limit encroaching upon the 5-cent fare zone of the Brooklyn surface system. The rapid-transit lines in Brooklyn, under the same ownership as the Brooklyn surface system, have approximately the same 5-cent fare limits and charge a second 5-cent fare to Coney Island.

To the north the rapid-transit limit gives a ride of about 14 miles from the center, or slightly more than one-third cent per mile, while in Brooklyn the 5-cent rapid-transit limit extends about 8 miles, giving a rate for the maximum ride of about 0.6 cent per mile.

To the west the Hudson Tunnel System charges a 6-cent rate for a distance of about 3 miles, equivalent to about 2 cents per mile. As extended to Newark, the fare on this line is 17 cents for about 9 miles, or approximately 2 cents per mile. This is probably the highest rate of fare charged by any rapid-transit system in these metropolitan areas, although it is stated that the total net income barely covers the interest upon its bonds, representing the large investment caused by its expensive submarine-tunnel construction. Another interesting feature of this operation is that for the entire distance above ground, in New Jersey, this line runs its cars over the main-line tracks of the Pennsylvania Railroad. The 60-trip monthly commutation charge to Newark is at the average rate of 1.06 cents per mile.

In Chicago upon the rapid-transit elevated system the 5-cent rate obtains to the terminals of all lines, or to the city limits. This 5-cent rate on the south extends for a distance of about 8 miles, and on the west and north for about 9 miles, giving an average rate for the maximum distance of about 0.6 cent per mile. Where this rapid-transit line extends beyond the city limits to the north, the 10-cent fare limit extends about 13 miles from the center, making the cost of the maximum ride about three-fourths cent per mile. To the west an interurban electric line connects with the elevated line, charging three 5-cent fares for the 6 miles to the 16-mile circle, approximately 2½ cents per mile.

In Philadelphia the rapid-transit system comprises only 7½ miles of a subway and elevated line running east and west and extending approximately 5 miles westwardly from the center, so that the maximum ride from the center is at the rate of about 1 cent per mile.

In Boston the rapid-transit and surface systems are operated jointly. Radiating from the center is a combined elevated and subway line extending to the north about 2½ miles to Charlestown and about 5 miles to Forest Hills on the south. There is also a combined tunnel and bridge line to Cambridge.

Conditions of passenger traffic.—The report of the committee on passenger traffic at the 1913 convention of the American Electric Railway Association reveals a number of aspects of the problem not usually considered in a discussion of rates and fares. Such a question, for instance, is that of varying the hours of factory closing so as to prevent the congestion of traffic due to the closing of all the factories at the same hour, with a resultant enormous "peak" load. In Rochester, N. Y., it is stated that the various manufacturing companies are cooperating with the railway company with the best results to both. In Kansas City, Mo., the largest industries are stockyards and packing houses, employing about 35,000 persons, and in this case the rush-hour problem and peak load are somewhat lessened by the fact that these are served by from three to six lines, on which extra cars are put in operation at closing hours. The lines conducted a trial, however, with Montgomery, Ward & Co., employing from 2,000 to 2,500 people, in furnishing cars for employees of that company at the various hours of closing. The company agreed to make the hours of closing 5.50, 5.55, and 6 p. m., dividing the force into three practically equal parts. Later the time was changed to 5.10, 5.15, and 5.20 p. m. Extra service was placed on the lines by the railway company to meet these conditions, and the result was most pleasing to the employees and managements of the companies concerned. In answer to the question whether such a plan was feasible or possible, the majority of the companies replied that it was not, and especially as applied to their local conditions. This feeling was stronger among the interurban and smaller companies than with the companies serving populations of 100,000 or more, quite a number of which thought such a plan would be of benefit, although no efforts had been made in that direction.

The recommendation of the committee in regard to another important point was that passengers should be permitted to ride in the front vestibules of closed cars. The main objection to such a rule is found to be the risk of accident due to distraction of the motorman's attention. This risk has been greatly minimized by the use of steel cars, stronger underframing and body structure, and "anticlimbers," and by the standardization of types and heights of platforms. In connection with this question should be mentioned the difficulty of enforcing at all times the order prohibiting riding on the front platform. In 1909 the Pennsylvania state railroad commission drafted a rule against permitting passengers to ride on the front platforms of cars. In the early part of 1910 the Philadelphia Rapid Transit Co. stated that during the afternoon rush hour it was impossible to enforce the order without employment of physical force, and that it would require the assistance of the police to remove passengers in this manner. In September, 1912, the Chicago City Railway issued a folder stating that on near-side cars passengers were not permitted to remain upon the platform, but from investigations it was found that this rule could not be or is not adhered to during the rush-hour travel, platforms being filled to capacity at such times.

On the other hand, many companies are realizing the value of this space for passengers, as well as the use of passengers as witnesses to accidents. During 1910 the prepayment cars of the Metropolitan Street Railway Co., New York, and the Third Avenue Railroad were provided with folding seats on platforms in order to secure as much seating capacity as possible. The latest Pittsburgh cars at that time had no front platforms. The new near-side cars in use in Chicago, Buffalo, and Philadelphia would tend to show that the ancient prejudice against having passengers on the front platform is being overcome. This is also true of the type of cars now being placed in use on the New York Railways, Pittsburgh Railways, Brooklyn Rapid Transit, and United Railroads of San Francisco, of the vestibuleless type in Kansas City, where the seating capacity has been increased 10 per cent, and of cars in use by various other companies.

The following figures are given by the claim department of a large urban system in regard to the number of passengers injured while riding in front vestibules of cars in collision accidents during the months of October, November, and December, 1912:

MONTH.	Number of collisions.	Passengers injured.
Total	90	5
October	26	3
November	32	2
December	32	0

This same company reported that a very large percentage of the witness statements of passengers in front vestibules are favorable to the company, and that the information obtained therefrom is most valuable.

It is found that the question of free transportation is governed quite largely either by franchises or by state laws, and these have recognized to a large extent local conditions in cities and in states. Information was requested from 217 companies and replies received from nearly all. Of the total number, 177 companies issue transportation to all employees and 38 companies issue transportation to a portion of their employees. Free transportation issued by the larger companies is limited in a majority of cases to trainmen, officers, and operating officials. It appears to be the general policy of the smaller companies to issue transportation in some form to all employees, and to be the general practice to allow the use of a badge or uniform for the transportation of trainmen. Other employees are furnished with tickets, card passes, coupon books, or limited-trip books.

In regard to transportation furnished employees' families, 104 companies reported that they supplied transportation to families of certain employees, while 106 companies reported that they did not issue such transportation. A large percentage of the companies replying in the affirmative are interurban. Out of 30 of the largest companies from which information was received, 25 do not issue transportation to employees' families; 4 issue transportation to employees' families; and 1 company reported issuing transportation to employees' families on interurban lines and no transportation to employees' families on city lines. The general form of this transportation is in trip passes or a limited number of coupons, and in a number of cases such transportation is issued only on request.

Out of 217 companies making replies to the question as to free transportation to outside persons, 60 companies issue transportation to police, 48 to firemen, 45 to public officials, 28 to employees of other roads, 20 to charity, 17 to the press, 8 to mail carriers, and 14 to miscellaneous recipients, and 18 companies issue no free transportation to nonemployees. A decided tendency is noted toward discontinuance of all such free transportation. It seems to be the general custom to allow free transportation of police and firemen, either in full uniform or upon presentation of badge.

In the majority of cases a reduction on the round-trip fare is allowed on electric railways. Several years ago the steam roads allowed apparently the same reduction as is now given by most electric lines. The steam roads have, however, recognized the necessity for increased rates of fare, and as the revocation of this reduction furnished one of the easiest means of increasing their earnings, such action was taken; and it has been proved, so far as they are concerned, that it is not necessary to make this reduction in order to stimulate traffic.

It has been found that the one great objection to doing away with this reduction is that without it there would not be any inducement to purchase tickets and, as a result, an additional temptation would be placed in the way of the conductor on account of a greater amount of cash passing through his hands. This is no doubt true, but it has been proved in several cases that a dishonest conductor can manipulate tickets almost as easily as by the straight "knockdown" of cash.

There seemed to be a general movement on foot among the various member companies to do away with the reduction on round-trip fares. There have been several changes of this kind made within the past few years, and it is reported by these companies that a very material increase in earnings has been shown, the argument being put forth by them that in consideration of the frequent and convenient service furnished by the interurban lines, it is not necessary to offer an additional inducement in the way of a reduction of fares.

Most roads, it is found, do not make any reduction on one-way tickets. In other words, most roads are charging the maximum 2 cents per mile cash fare for one-way trips, making no reduction when tickets are purchased. Reductions are given in most cases on commutation tickets and mileage books. This practice is quite general, and, indeed, is almost universal where roads charge 2 cents per mile. There are a few roads charging less than 2 cents per mile which do not give any reduction. However, in almost all cases where an excess cash fare is charged over the one-way ticket fare, the tickets sold represent about 90 per cent of the total one-way fares.

Prepayment fare operation.—At the meeting of the New York State Electric Railway Association in 1913, reference was made to the results obtained in fare collection by the prepayment method, or "pay-as-you-enter" plan. A notable demonstration of its value was made by the introduction of prepayment cars on the Fifty-ninth Street line of the Third Avenue Railway, New York. The change from the ordinary nonprepayment car, made overnight, resulted in a revenue increase of 9½ per cent, notwithstanding the fact that the car mileage was reduced 4½ per cent. The annual report of the Chicago Railways Co. for the year ended January 31, 1912, showed an increase in gross receipts of 63 per cent during the preceding four years. There are some 1,500 pay-as-you-enter cars in that company's service, and while this increase in receipts can partly be accounted for through the normal growth of Chicago, and of the railway's business, a considerable margin must be attributed to improvement in fare collection. The fare box has been extensively introduced as an adjunct to prepayment operation. The value of this apparatus is contained in its moral influence on the conductor, and when it fails mechanically its influence and many nickels are lost at the same time. The remarkable development of the fare box indicates that mechanical failures are few and general cost of upkeep is becoming very low. On the Third Avenue Railway, New York City, for instance, two men suffice to maintain in mechanical efficiency about 550 boxes.

An interesting method or system of fare-box collection has been in use on the lines of the Rhode Island Co. in Providence for six or seven years, nearly 1,000 boxes being now in service. The register is carried by the conductor. It weighs but 21 ounces, and is a small nickel-plated box having a coin slot on one side, through which the passenger inserts the nickel, the coin being drawn into the device by the mechanism of the register as soon as its edge touches certain levers within the slot, whereupon the fare is registered automatically. The coin passes entirely through the register immediately after it enters the receiving slot, ringing a bell in the register as it is recorded, and is delivered into an open receiving compartment at the bottom of the device, thus becoming available for making change. When the coin has once entered the slot it can not be withdrawn but must pass through the register into the receptacle beneath. The entrance to the passage is automatically closed by the descent of the coin, and no additional coin can be inserted until the resetting of the opening by the conductor.

The equipments carry two totalizing registration counters, one for nickels and one for dimes, and in the latest type of register an additional counter is provided for metal tickets. It is not intended, however, that the public should pay fares in dimes, and while the dime-registration apparatus is built to withstand the same hard service as that imposed upon the nickel-recording mechanism, the rules of the company require nickel payments alone. Signs carrying instructions for passengers as well as a request for them to have nickels ready for payments are posted in all of the Providence cars. It is, however, possible for the conductor to make change and to use both hands in so doing, since the register is provided with a ring through which the conductor passes his middle finger, and when both hands are required the register is allowed to turn upon the finger and drop after the manner of the ordinary transfer punch.

With this system the conductor has nothing to do with the registration and does not handle the money until after it is registered. While the passenger and the conductor appear to be alone in this exchange of money for service, the company is actually present interposing the register between them. The registration mechanism is sealed at the factory, and traffic records are obtained by subtracting successive readings. On the lines of the Rhode Island Co. and elsewhere, experience with this system shows, it is said, that at least 90 per cent of fares formerly lost to the company are saved by its use.

The register is in no sense a money container. It operates in full view of the conductor and the passenger, can be held in any position or at any angle best suited to the passenger's convenience or to the conditions prevailing in the car, and accommodates in its lower receptacle eight or ten fares, or at least as many as a conductor would ever accumulate with his outstretched hand before examining and pocketing them. The registration has a total capacity of 99,999 nickel readings.

The conductor stands behind the railing in the platform vestibule, and the portable character and small size of the register are important points in the facility with which traffic can be handled. The space taken up is negligible, and in case the conductor is obliged to make change for one or more passengers in an entering line he can save time by presenting the register to others in the line without waiting for all to pass a predetermined point. Actual counts show that 80 passengers have been loaded and their fares all taken in two minutes on a single car making a stop in front of a large factory at closing time. In some cases individual registers handle as many as 3,000 fares per day.

Apart from the accuracy of the system and its removal of temptation from the conductor, it saves the conductor time otherwise consumed in manipulating the register cord or bar, and also obviates the false registration of fares by passengers who mistake the register cord for the bell cord. On the older cars of the Rhode Island Co. the conductor makes the usual personal collection from passengers on the inside, and the use of the portable register has been found a convenience to the public through its avoidance of jerky attempts on the part of short conductors to reach the ordinary register cord. The collection of fares by this method on crowded open cars has been very successful. No new printed reports of any kind were required in Providence on account of the adoption of this system. Conductors use the same trip sheets as before. Registers are leased by the maker on terms which cover inspection and repairs. It has been found that in the extremely few cases where a register has been stolen the conductor has found the theft so great a burden that the register has been anonymously returned.

In the report of the committee of the American Electric Railway Association on fares and transfers, presented at the meeting in October, 1913, some interesting data were given as to fare boxes. Replies to inquiries were received from 63 companies. Of these, 31 reported gross receipts annually of less than $1,000,000, the remainder having receipts greater than that amount. The use of prepayment cars was reported by 60 per cent of the smaller companies and 80 per cent of the larger ones, a total of 45, or 71 per cent of the whole number. The practice of the 45 companies operating prepayment cars was shown by the replies to be about equally divided as to the use or nonuse of fare boxes. A further equal division was found with respect to the locked and the nonlocked box, the former being the type which renders fares inaccessible to the conductor; and the same condition was found in regard to the use of fare-box registers. Four companies using a nonregistering locked box used a fare register on the car, and six companies did not use such a register under such conditions. Nine companies used fare registers besides registering fare boxes, and two did not.

The reasons given for use of fare boxes of the various types are as follows: Eight companies favor the registering nonlocked fare box because the change is available for the conductor, and four give other reasons. Two companies are using both types of boxes, but each prefers the registering fare box because it delivers money to conductors and gives them available change. Seven companies favor the locked fare box mainly on account of its cheapness and simplicity. One company was experimenting with both types, and one with a registering nonlocked box. Most of the locked nonregistering fare boxes receive any coin; three take cents, nickels, and dimes; and one, nickels, dimes, and quarters. Twelve of the registering nonlocked boxes take cents, nickels, and dimes; two take nickels and dimes only.

As to transfers, it was found by the committee that the majority of the smaller companies, such as issued less than 60,000 transfers daily, did not issue transfers on transfers, but that the larger companies did so, though in the majority of cases the retransfer privilege was limited. The majority of the smaller companies registered transfers, although the reverse was the case with the larger ones. A separate or double register was used in most cases for this purpose.

Most of the companies which followed the practice of registering transfers reported more or less effort to verify collections with register readings, and discipline for failure to register transfers in the same manner as in the case of failure to register fares. The general consensus seemed to be that it was impracticable to do more than check, in a general way, the number of transfers issued, destroyed, or given away, particularly when a large number of transfers was involved.

A difference of policy was observed in checking transfers to determine whether they had been properly honored by the conductor. Certain of the roads receiving but a few thousand transfers daily checked them out with care as to date, time, direction, etc., while some roads receiving less than a thousand transfers a day either made no check at all or made it at infrequent intervals only.

About half of the companies reported that a conductor who had improperly honored transfers was called before the superintendent or his representative. Two companies gave demerits in such cases. Several reported that men were cautioned and subsequently disciplined for repetition of the offense, while 12 companies charged the conductor for each irregularity.

The percentage of transfers given to conductors and not issued varied between the approximate limits of 15 per cent and 50 per cent, although in some cases this percentage was reported to be actually nothing. The proportion of issued transfers which were finally collected varied between the approximate limits of 75 per cent and 95 per cent, decreasing on the larger roads.

From the replies received the committee was of the opinion that the transfer which provides for the indication of the month and day by punch and notch marks is well adapted for use on those lines where the number of transfers honored daily is relatively small. The transfers which are stamped or printed with a figure to indicate the day of the month are somewhat more subject to waste. The transfers which are perforated by a machine before being given to a conductor are not quite as economical as either of the other two types of transfers, but obviously involve less waste than those which bear the printed day and month and are only good for one particular day. The dated transfer which may be used only on one day involves more waste than any of the preceding types of transfers mentioned, and as it involves the use of more than one standard form of transfer, it opens the way to additional abuse; but there may be certain local conditions which offset these undesirable features. The coupon transfer is expensive, but it appears to possess marked advantages in cases where a passenger is permitted to transfer more than once.

The discussions that took place at the convention revealed an absence of unanimity in regard to these important matters, indicative of the difficulty of reaching any standard practice. For example, Mr. W. F. Ham, Washington (D. C.) Railway & Electric Co., said that his company was probably one of the few that had not experimented extensively in the use of fare boxes. That, however, should not be taken as a condemnation of the use of fare boxes, but simply as a statement that in the city of Washington the fare box did not seem to be of value, because of the fact that about 80 or 85 per cent of the business was done on tickets, leaving only about 15 per cent on a cash basis. So far as his experience had gone, the company felt that it could do better without the use of the fare box. To show, however, how different people reached different conclusions, Mr. Ham said that at about the same time that his company did away with the fare box the Capital Traction Co., operating in the same city, adopted it, and had practically the same conditions to contend with. Hence there was no unanimity of opinion in Washington as to whether fare boxes were good or bad. According to his experience they did not give good results, and while he thought that his company did not have the best kind of a fare box, still there was nothing in it that looked particularly attractive and it was decided to give up the use of the device. His company had used both registering and nonregistering boxes.